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Research paper

Site suitability analysis for construction of an airport in the middle Euphrates – Iraq, using a GIS-based AHP technique

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Abstract: This article discusses in a simplified manner how to use the multiple functions of the Geographic Information System (GIS) to support the engineering decision for vital and important sites that require the decision-maker to have a high degree of certainty, such as the decision related to choosing the best location for the airport among several sites. This paper aims to provide a practical model that allows for a decision support system on how to adopt a GIS software by both its part Arc-Map and Arc-Catalog combined with analytic hierarchy process (AHP) method to make strategic decisions by spatial and non-spatial analysis to choose the appropriate site for the project as those related to choosing an airport location. Nineteenth criteria were considered to analyze the study area which is represented by three governorates of the middle Euphrates region in Iraq, Babil, Kerbala, and AL-Najaf. Finally, the research presented a practical and efficient approach for the decision maker to select the appropriate location for the airport based on the value of the highest suitability index.

Keywords: AHP, Arc-Map, Arc-Catalog, Middle Euphrates region

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1. Introduction

As engineers on various projects, every day we may have to make decisions, the size and importance of these decisions are closely related to the size and importance of the project. Decisions should be made wisely under different circumstances with different amounts of knowledge about alternatives and outcomes [1]. The decision making process is one of the priorities for the success and sustainability of any construction project, as in most construction projects the decision-makers have to make decisions on an almost daily basis and they must have a logical justification for these decisions, as wrong decisions have a heavy legacy in terms of quality and time, and therefore cost and project success [2]. There are still other, unknown methods for making decisions on construction sites, despite the accumulated experience on which decision makers can rely on those sites [3]. Making typical decisions requires the decision-maker to arm with technology and appropriate application to do so. Multi-criteria decision making (MCDM) technology is one of the applications established to support the decision-maker mechanism. MCDM is used in many fields, including airports, which is used to derive the selected criteria weights. The analytic hierarchy process (AHP) is one of the most common tools in MCDM [4] which was proposed by Saaty [5], which is a highly effective tool for tackling the complex decision-making processes that include many options and alternatives [6], its work is based on the pairwise comparison matrix system and is a powerful and easy tool for qualitative and quantitative analysis of multi-criteria problems [7], it also provides a unique advantage as the expert can check the consistency of weights by checking the consistency ratio (CR) in pairwise comparisons instead of using the direct selection method for weights. Many studies have used the AHP method with GIS to evaluate the weights of the criteria in determining the appropriate sites [8–15]. GIS is one of the most important tools of the decision support system, especially in the field of spatial projection. Geographical Information Systems (GIS) is an increasingly important and widely accepted technology as a means of decision support in resources, infrastructure, environmental management, spatial analysis, and urban planning [16]. GIS technology mixes common database operations such as statistical analysis and inquiry with the unique visualization and geographic analysis benefits offered by maps. In other words, GIS is a tool of great importance in the integration between database systems and maps [17]. In the recent past, the airport was included under the term (Aerodrome), which is the place from which aircraft flight operations are carried out, regardless of whether they involve cargo or passengers or not. As for the modern term under the title (Airport), it refers to a certain stature (having satisfied certain certification criteria or regulatory requirements) that an aerodrome may not have achieved [18]. Airport construction is associated with economy, technology, national politics, military affairs, transport networks, tourism geographical environment ,and industrial enterprises [19], thus, the problem of airport planning (internal airport planning and on-site planning) is no longer a simple problem, but rather a special process that deals with a complex and dynamic engineering system and not a simple facility planning process. One of the indicators of the development of countries is the number and quality of airports in this country, where the International Civil Aviation (IOCA) Organization classifies airports according to their size, the service provided by them, as well as the quality of their aircraft. In Iraq, there are six airports distributed from north to south of Iraq, and the seventh airport is under construction in Karbala governorate by comparing the number of airports between Iraq and neighbouring countries, it is noted that Iraq is in the last rank, and this does not fit in terms of the relative importance between area and population [20]. In most developing countries, and in Iraq in particular, the difficulties and obstacles facing large and strategic projects do not lie in the designs or the cost, but rather in the method used in choosing the appropriate site for the project, which is subject to quick, ill-considered decisions or political wrangling, which leads to the exclusion of the appropriate location for the project in many sometimes the idea of the project fails, and this is because the fieldwork and the standards followed may not be compatible with the type of the project. This research presents a simple method according to analytical logic to predict the appropriate location for establishing an airport from among many proposed sites.

2. Previous studies

Several studies have been conducted to obtain the best location for airports, where some researchers went to choose the location of the civil airport through the use of GIS [21], to evaluate the choice and orientation of passengers [22], or by relying on different indicators to form models for selecting the location of the airport [23].

From the literature review for choosing the best airport site, the study of Bambiger and Vandersypen [24] who adopted in their study qualitative multi-criteria evaluation of the airport site problem, Neufville and Keeney [25], who applied the multiple, attributes method to search the airport site among two alternative sites for the airport near Mexico City.

Saatcioglu [26] used three methods of programming models to determine the location of the airport, and Horner [27] conducted a study that includes a review of the location of airports and airstrips in Ireland by applying the technique of the location-allocation algorithm.

Janic and Reggiani [28] found the same results when applying three multi-criteria decision-making methods, the analytical hierarchy process, simple additive weighting, and the technique for order preference by similarity to the ideal solution on seven pre-selected locations as potential locations for selecting a typical airport location for a virtual airline of European Union.

As for Wang [29] he created the index system of the model and used the knowledge system of the expert. Sur and Majumder [30] used the mathematical entropy model and the cost of construction per person as criteria to help alternatives to locate the airport in developing countries. Yang et al. [31] studied the possibility of determining the optimal locations of airports by expanding a quantitative method, taking into account the possibility of access to airports by land and air transport.

Sennaroglu et al. [32] conducted a study to select the best site for the military airport from among many candidate sites, using the multi-criteria decision technique. The study of Zhao et al. [9] focused on the necessity of avoiding the establishment of an airport on the migration routes of birds.

Finally, the study of Arkan and Sherida [4], which includes choosing the appropriate location for the airport, by taking 23 criteria related to the local features of the study scope, in Libya, where the researchers used analytic hierarchical process and rank order centroid with GIS to evaluate the weights of criteria for choosing the appropriate location for the airport.

As a summary of what was mentioned above in the literature review, it was found that there are two approaches related to the airport site selection problem, namely, the optimization approach (the mathematical approach), and the ranking approach (factors assessment), and in both approaches, there are some defects, for example in the problems of the ranking approach, the primary objective is to pre-identify potential locations for airports to be evaluated later, although some possibilities may be inadvertently overlooked, while one of the disadvantages o of the optimization method is that the criteria used are very narrow, which in most cases is related to the distance from the airport and the number of residents [33]. To overcome the shortcomings of the approaches mentioned above and to develop the quality of solving the problem of the airport location, integrating GIS software with MCDM methods is adopted in this study.

3. Study area

The Middle Euphrates is the geographical region located south of the capital Baghdad in the Euphrates river basin and is considered the most fertile area in Iraq, which includes five governorates, namely Najaf, Kerbela, Al-Diwaniyah, Babel, and Al-Muthanna. The study area is represented by Al-Najaf, Kerbela, and Babel governorate, which is located between the longitude lines from 42°42′20.704″ to 45°9′23.81″ E and latitude lines from 29°52′21.37″ to 33°5′12.44″ N, where three governorates were chosen for the study area among five governorates for the reason that the previous idea of the government was to establish an airport in one of the three aforementioned governorates, currently there are two airports in the study area and the other is under study, which are Al-Najaf international airport in Al-Najaf governorate, Karbala International airport in Karbala governorate and the proposed site for the construction of Babel International Airport in Babil Governorate, in addition to the foregoing, these three provinces contain religious shrines that make them a focus for attracting visitors from most of the Islamic world. The research hypotheses include choosing the best site for establishing an airport by analyzing the study area according to international criteria for selecting airports, as well as ignoring the current and proposed sites for airports and considering them as an exposed area and an extension of the surrounding area before its establishment. From the literature, the factors most frequently considered for selecting airport locations are the airport service cover distance and the population size [33]. It was noted that the population of the three governorates, Babel, Karbala, and Najaf was 2,231,136, 1,316,750, and 1,589,961, respectively, according to the data of the Iraqi ministry of planning – Central Bureau of Statistics, 2021. In general, to choose the site, the analysis process goes through several stages, starting from the process of spatial analysis of the data acquired for the study area to neutralize its size little by little to a smaller area and thus can be easily dealt with [34]. The geographical location of the study area, roads, rivers, and other information are shown in Fig. 1.

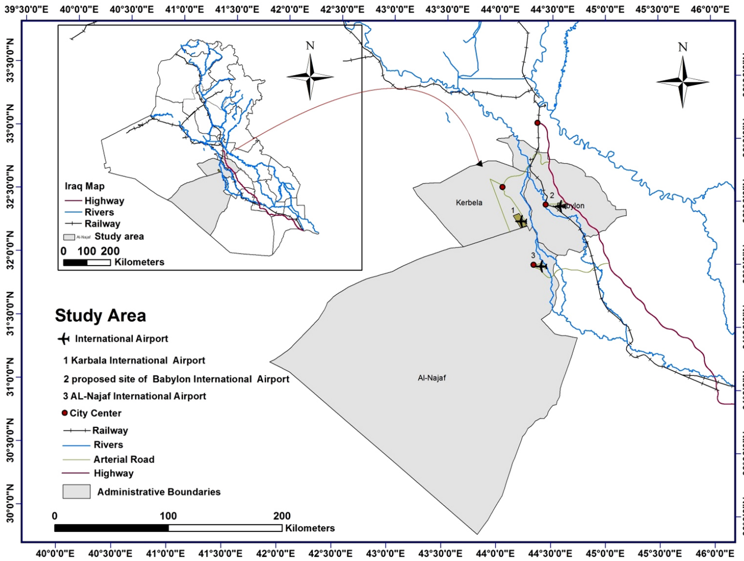

Fig. 1. Study area and location

4. Methodology

Expert choice version 11 software for MCDM (AHP method) and Environmental systems research institute GIS (Esri ArcGIS version 10.8 software) were used to site suitability analysis and thus determine an airport location according to the flowchart shown in Fig. 2.

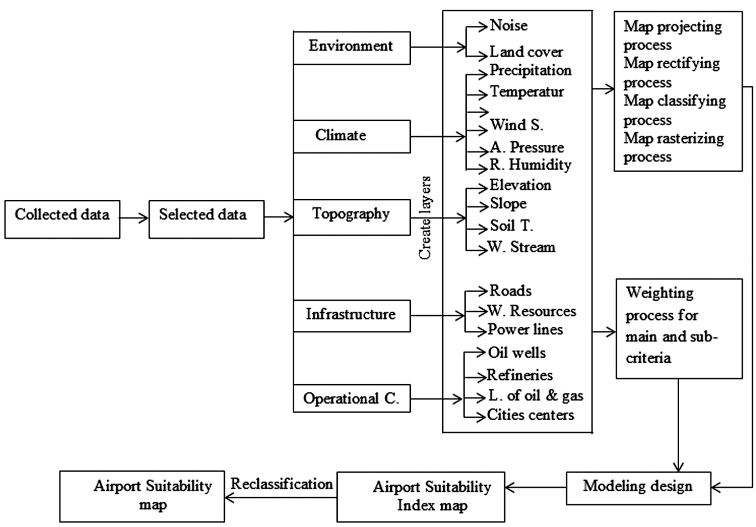

Fig. 2. The flow chart of the methodology

4.1. Selection of criteria

One of the necessary steps for most studies is a selection of criteria, which are a starting point for collecting the necessary data on which the effectiveness of decision-making steps is built. At airports, the adoption of the relevant standards is entirely dependent on the local features of the study zone, regulations (International Civil Aviation Organization (ICAO), applicable rules [35–37], literature review of previous researchers [26,27,31], Federal Aviation Administration (FAA) [38], availability of the data including maps, expert opinion documents, etc. Five main categories of decision criteria were used for selecting airport locations; namely, environment consideration, topographical conditions, infrastructure facilities, climatic factors, and operational conditions. These main criteria can be divided into several secondary criteria. Hence the total number of the applied criteria is 19, as shown in Table 1.

Table 1. Criteria of the study area

S.NO	Criteria	S.NO	Criteria
1	Distance from residential regions (noise and pollution)	11	Soil characteristics
2	Land cover	12	Distance from water streams
3	Precipitation	13	Proximity to roads
4	Temperature	14	Proximity to water resources
5	Clearness index	15	Proximity to power lines
6	Wind speed	16	Distance from oil wells and fields
7	Atmospheric pressure	17	Distance from refineries and industrial factories
8	Relative humidity	18	Distance from lines of oil and gas and
9	Elevation above sea level	19	Proximity to cities centers
10	Slope of land		

4.2. Data collection

Data collection is a very important process to assess and integrate the study, in this study, the input data were collected from a variety of sources, and these sources differ in terms of resolution. To make this data applicable so all this data will be geo-referenced within the GIS environment using the Transverse Mercator projection system (WGS1984 UTM Zone 38 N). Then, numerous steps were followed in GIS to get the final required layers (such as clip, convert, proximity, overlay, and extract) and, finally, changing those vectors map to a raster format, Table 2 shows the data for the study zone.

For climate data: (temperature, precipitation, atmospheric pressure, wind, humidity, clearness index), which was gotten from NASA Imagery Satellite (power.larc.nasa.gov) and making the layers as the following: 1. Preparing a grid of points covering the study

Table 2. Data collected for the study zone

Criteria	Source	Utilized to Create Layer
Slope, elevations, water streams	United States Geological Survey (USGS) Satellite Imagery [39] earthexplorer.usgs.gov	Slope (%), elevation (m), distance from water stream
Roads, power lines, water resources	Open Street Map Satellite Imagery [40] www.openstreetmap.org	Proximity to roads, proximity to power lines proximity to water resources
Precipitation, temperature, wind, atmospheric pressure, clearness index, humidity	National Aeronautics and Space Administration Satellite Imagery [41] power.larc.nasa.gov	The appropriate degree of temperature (C), the suitable wind speed (m/sec), the value of atmospheric pressure (KPa), the higher clearness index, the less value of relative humidity.
Oil and gas lines, oil fields and oil wells, refineries	Petroleum geology of Iraq (hard copy)	Distance from lines of oil and gas, distance from oil wells and discovery fields, distance from refineries and industrial factories
Land cover	Esri Releases New 2020 Global Land Cover Map [42]	Selecting the appropriate land
Soil characteristics	Atlas Iraq map 1:5,000,000 (hard copy)	Select the suitable type of soil

area well, in this study, 50 points were selected, distributed regularly over the study area; 2. From the NASA website, the required study data is obtained, represented by the latitude and longitude of each point, and the value of each criterion according to the unit of measurement, provided that the period time for measurement and the type of data (daily, annual) are predetermined which is exported in the form of an excel file; 3. Next for every point in the grid, the average of the required data is calculated; 4. After that, this data of every point is entered into the GIS program to GIS software and by the command of (3D analyst tools – Raster interpolation – Kriging) from Arc toolbox the raster layer is obtained. Later, starting with version 10, Esri Company developed a tool ArcGIS Editor OSM which can use directly by the software to download shapefiles of infrastructure for any required study zone.

4.3. Reclassifying and weighing of criteria

To set criteria in layers and then performing the weighted overlay process for all layers, this requires that the criteria be in the same units usually, and therefore requires standardization to make the units of measurement uniform – during this process quantities typically lose their measurement units as well as their dimensions [43]. To perform the weighted overlay process and then produce the suitability index map, it requires converting all the input layers into raster layers and reclassifying them to be included in this process as shown in Fig. 3, Fig. 4, Fig. 5, Fig. 6 and Fig. 7. Information available from expert

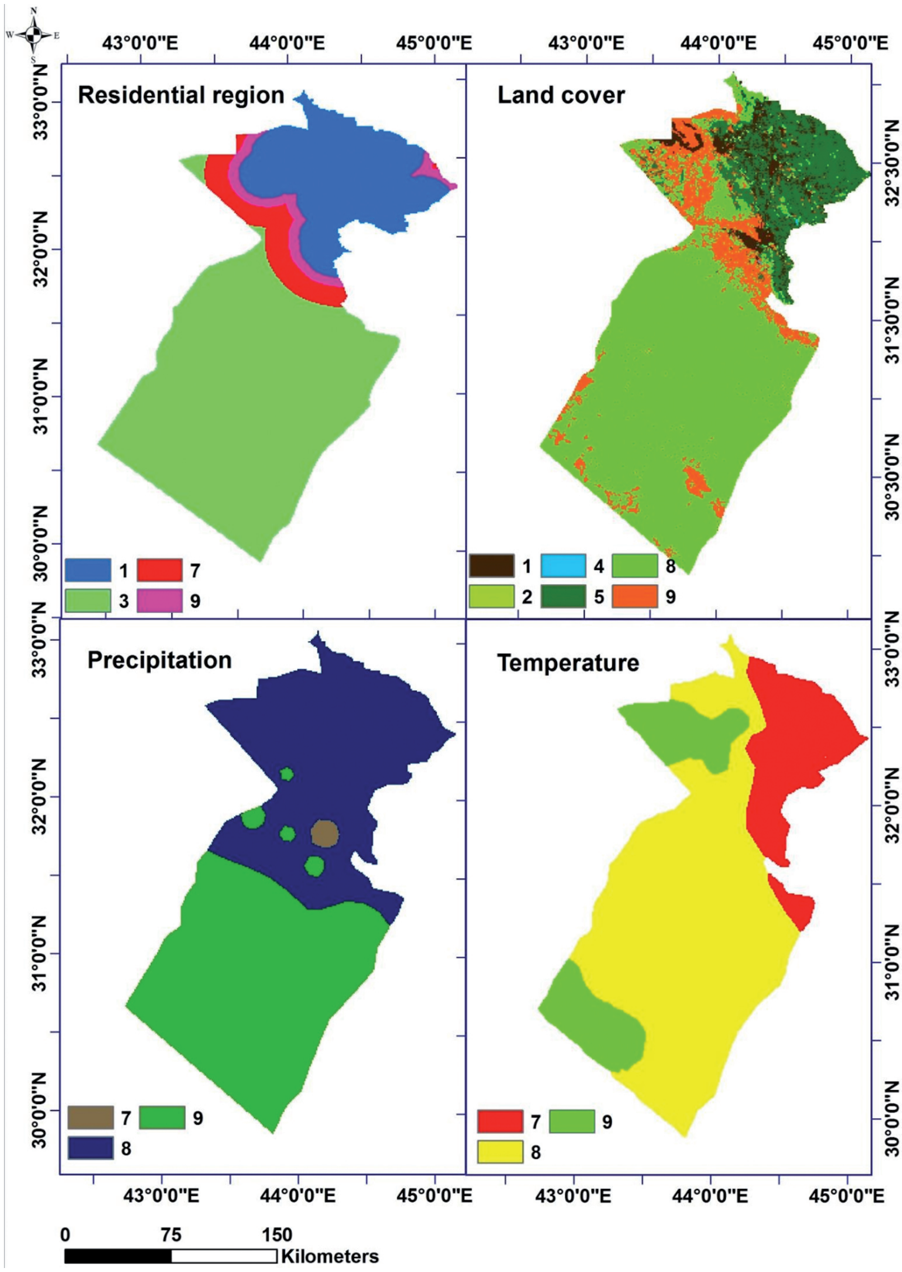

Fig. 3. Reclassified raster layers for the residential region, land cover, precipitation, and temperature

opinions, particular specification and literature review regarding safe distances around the airport, adequate distance from obstructions and infrastructure available with the rest of

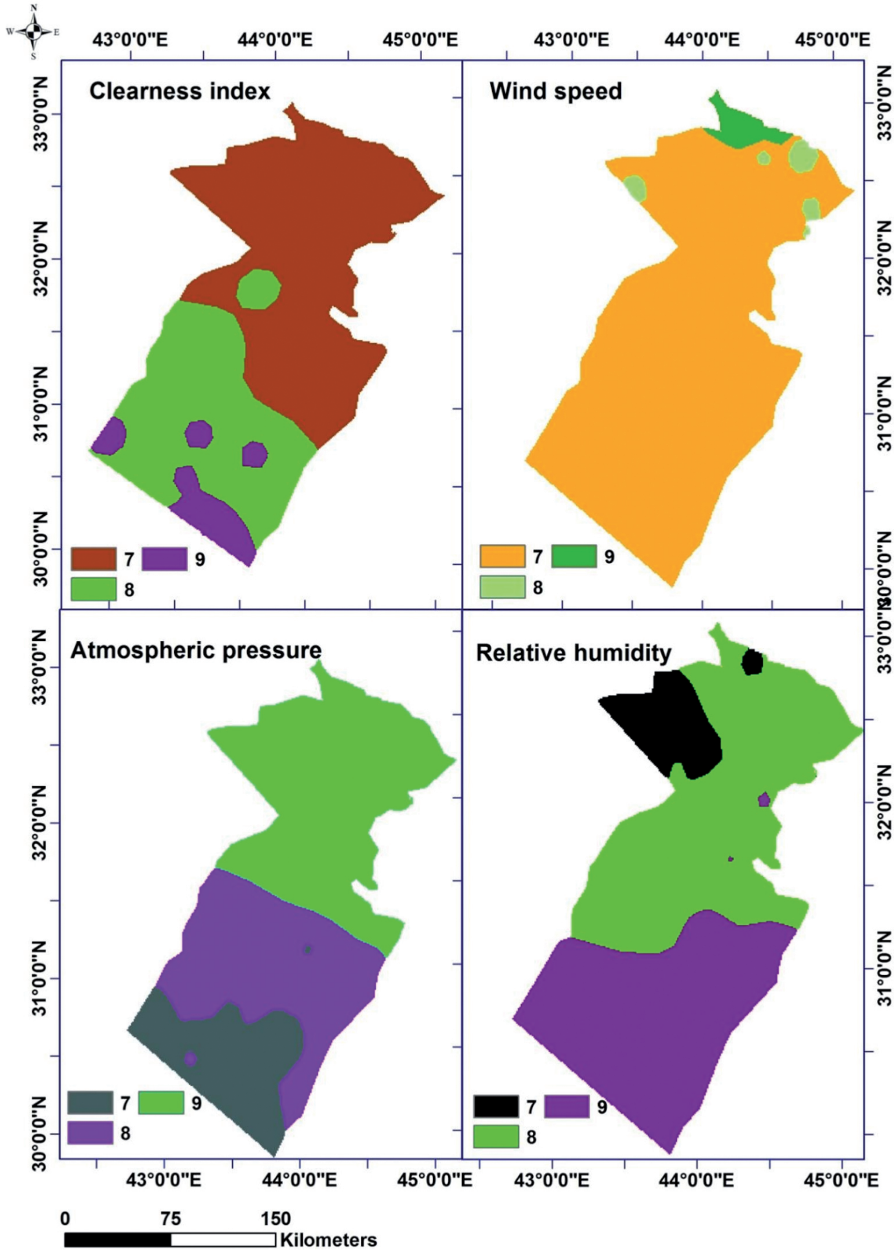

Fig. 4. Reclassified raster layers for clearness index, wind speed, atmospheric pressure, and relative humidity

the qualifications needed to set the location of the airport were used to determine the reclassification by setting rating values from 1 to 9 (from least to most convenient.), as shown in Table 3.

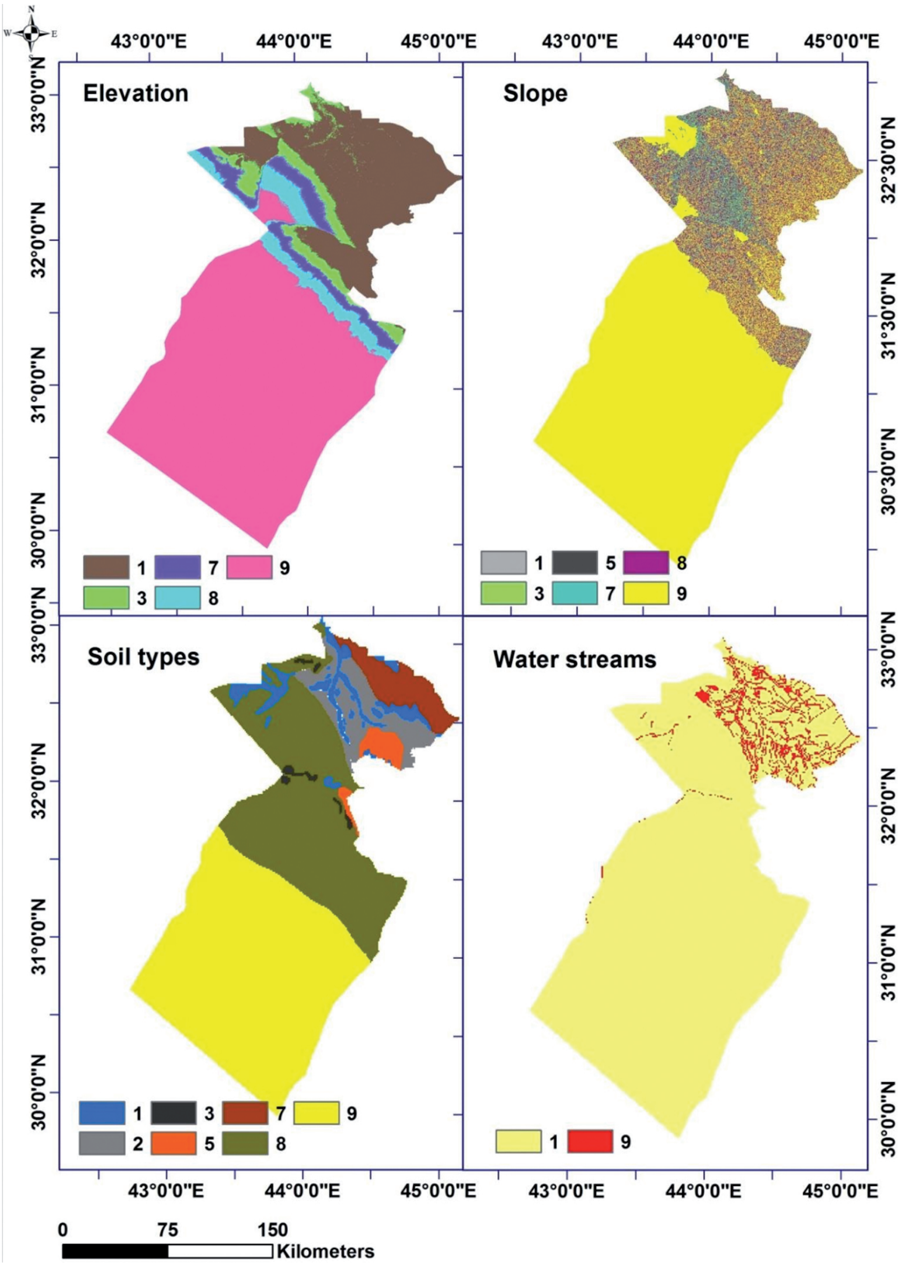

Fig. 5. Reclassified raster layers for elevation, slope, soil types, and water streams

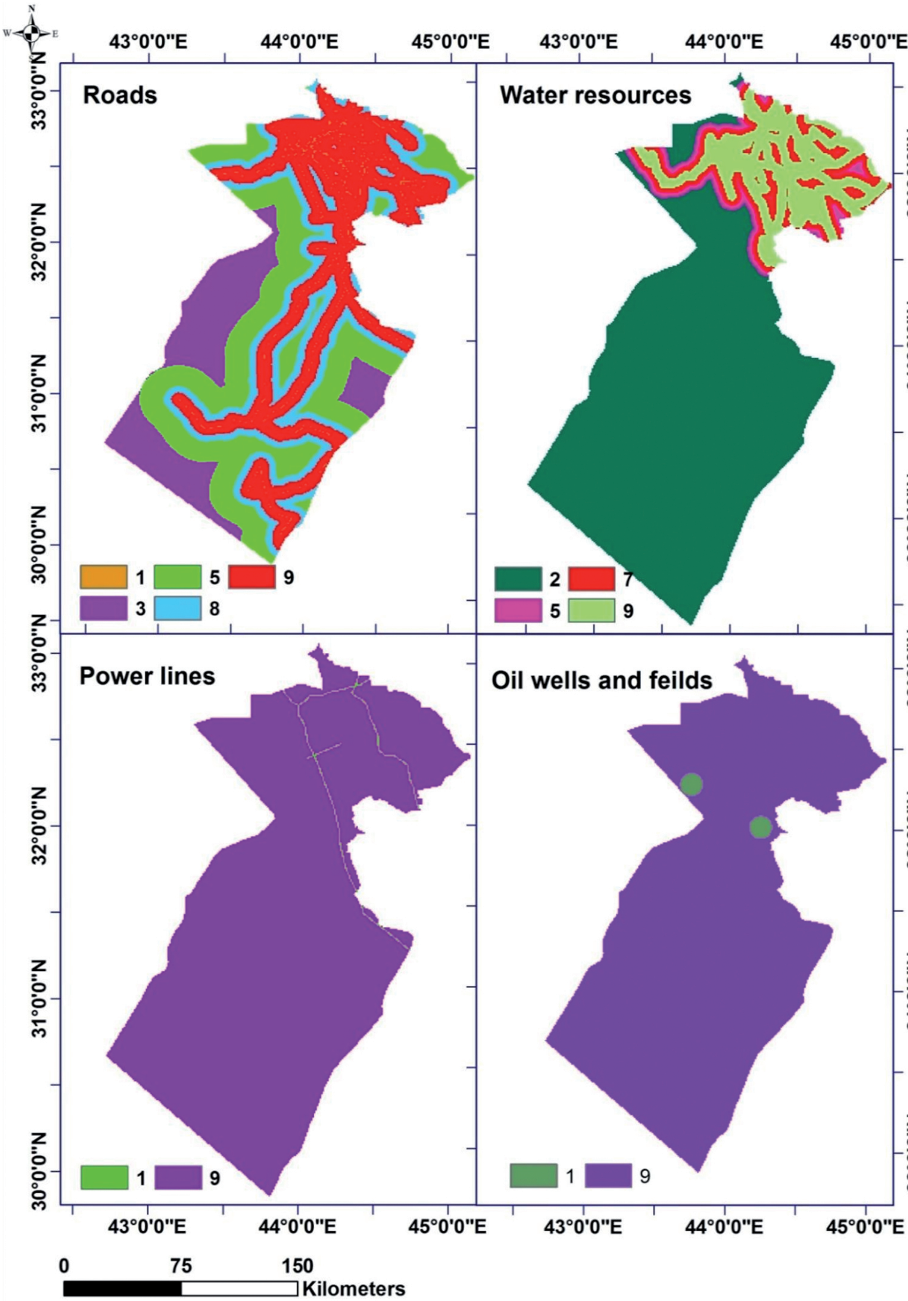

Fig. 6. Reclassified raster layers for roads, water resources, power lines, and oil wells and fields

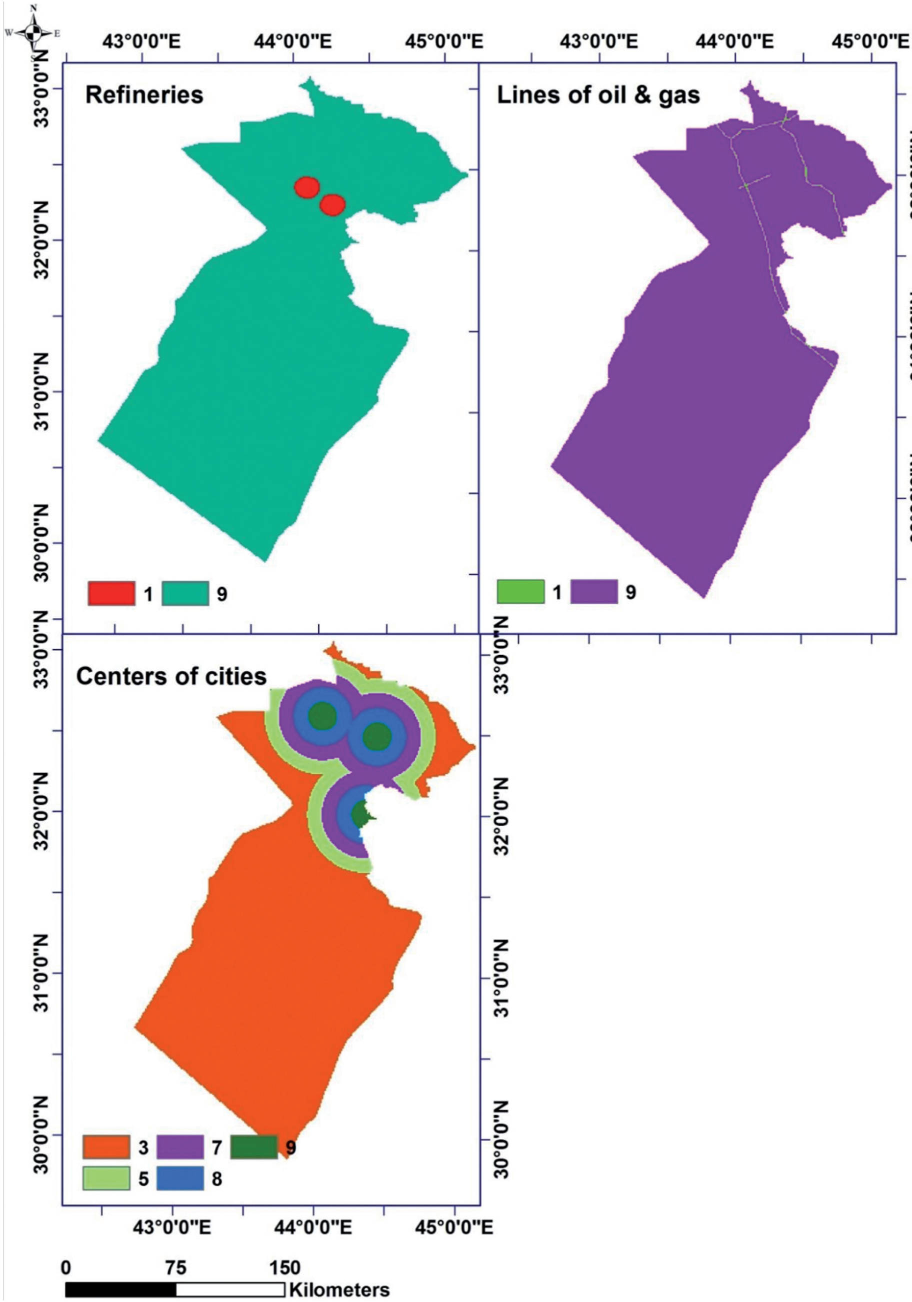

Fig. 7. Reclassified raster layers for refineries, lines of oil and gas and centers of cities

Table 3. Reclassification of input layers

Main Criteria	Sub-Criteria	Reclassification	Score	Source
Environment Considerations	Distance from residential regions (Noise and pollution)	<18,000 m 18,000÷25,000 m 25,000÷40,000 m >40,000 m	1 9 7 3	[35], [44], [45]
	Land cover	Bare ground Rangeland Crops Flooded vegetation Trees Built Area Water	9 8 6 4 2 1 1	[46]
Climatic factors	Precipitation (mm/day)	0.137÷0.271 0.2711÷0.405 0.4051÷0.539	9 8 7	[36]
	Temperature (C)	36.031÷36.837 36.8371÷37.643 37.6431÷38.448	9 8 7	[36]
	Clearness index	0.675÷0.682 0.6821÷0.689 0.689÷0.697	7 8 9	[35]
	Wind speed (m/s)	3.475÷3.759 3.7591÷4.043 4.0431÷4.328	9 8 7	[35], [37], [38]
	Atmospheric pressure (KPa)	96.351÷97.839 97.8391÷99.327 99.3271÷100.814	7 8 9	[36]
	Relative humidity %	30.006÷32.534 32.5341÷35.062 35.0621÷37.590	9 8 7	[36]
Topographical	Elevation (m)	0÷37 37÷60 60÷85 85÷112 112÷127	1 3 7 8 9	[36]
	Slopes (%)	0÷2.29 2.29÷4.25 4.25÷6.87 6.87÷10.15 10.15÷13.7 >13.7	9 8 7 5 3 1	[36]

Continued on next page

Table 3 – *Continued from previous page*

Main Criteria	Sub-Criteria	Reclassification	Score	Source
Topographical	Soil type	Stony desert land Sand dune land Lake Alluvial clay soil Saline lake bottom land Active dune land Periodically flooded soils Basin depression soils River levee soil Mixed gypsiferous desert land Silt soil Poorly drained land	9 3 1 5 1 1 1 1 7 8 7 2	[35]
	Distance from water streams	<300 >300	1 9	[47]
Infrastructure	Proximity to major roads	<100 m 100÷5000 m 5000÷10000 m 10000 m- 25000 m >25000	1 9 8 5 3	[35], [48]
	Proximity to water resources	<3000 m 3000÷6000 m 6000÷9000 m >9000 m	9 7 5 2	[35]
	Proximity to power lines	<3000 m 3000÷6000 m 6000÷12000 m >12000 m	9 7 5 2	[35]
Operational conditions	Distance from Oil wells and fields	<8000 m >8000 m	1 9	[49]
	Distance from Refineries	<8000 m >8000 m	1 9	[35], [50]
	Distance from Lines of oil and gas	<500 m >500 m	1 9	[35], [51]
	Proximity to cities centers	<10000 m 10000÷20000 m 20000÷30000 m 30000÷40000 m >40000 m	9 8 7 5 3	[35]

5. AHP implementation

AHP is a structured technique for dealing with complex decisions based on mathematics and psychology by providing a comprehensive and rational framework for structuring decision problems, setting goals and criteria, and evaluating alternative solutions [52]. It is clear that the task of evaluating the weights of the factors depends mainly on the understanding of the attributes of the factors and the characteristics of the study area, as well as the expertise of the expert related to the process of weight evaluation. However, the process of improving the evaluation and weighing of standards using techniques such as AHP has seen significant efforts to achieve it [53]. The hierarchical analysis process consists of several logical and systematic steps that include analyzing the problem hierarchically, and include a general goal at the top, a series of choices for each goal, and finally, a set of criteria or features that link the options and goals together, where the graph represents the first step of the analysis of the problem in In light of the general objective, criterion and decision alternatives, where the pyramid starts from the top by fixing the problem and clarifying the main criteria at the second level, and then the decision alternatives (secondary criteria) at the next level as shown in Fig. 8. After the graphic representation of the target and alternatives it will go to the step of forming a series of pairwise comparison matrices (PCM), where the experts assess the relative importance of the criteria for each pairwise comparison matrix using a scale from 1 to 9 as shown in Table 4. Saaty [54] denoted the specified nine-item measure, in which 9 means absolute preference, 7 is highly probable, 5 is probable, etc. until 1 is of equal importance.

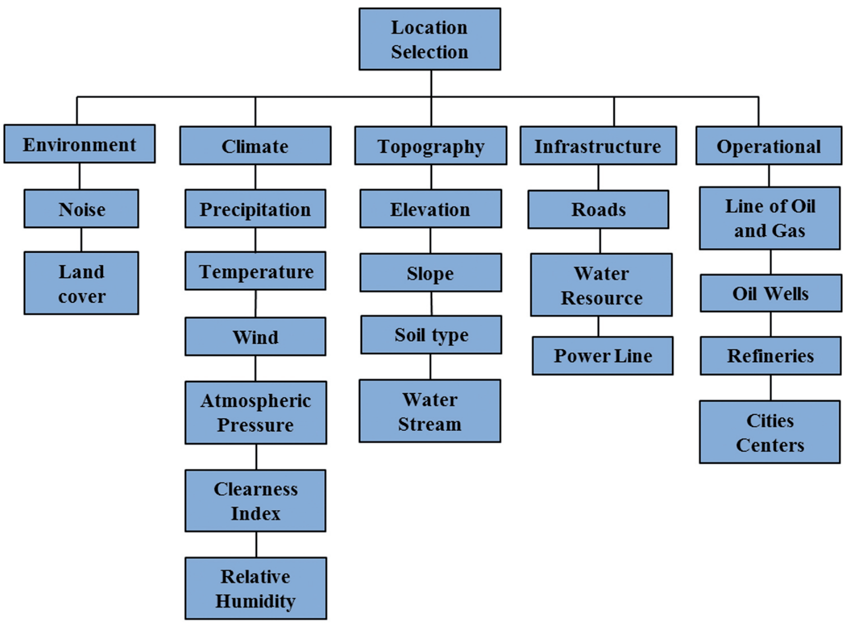

Fig. 8. Hierarchy structure of main and sub-criteria

Table 4. The comparison scale in the AHP method [55]

Value of a, b	Interpretation
1	Objectives a and b are of equal importance
3	Objective a is moderate importance than objective b
5	Objective a is strong importance than objective b
7	Objective a is very strong importance than objective b
9	Objective a is extreme importance than objective b
2, 4, 6, 8	Medium values

Concerning the rest of the steps of AHP analysis, it includes several mathematical operations, which must start with the design of a square matrix, which is characterized by the following conditions [56]: 1. Its diameter must be 1 integer because it represents the comparison of the criterion with itself; 2. The values above the diameter are equal to the inverse of the values below the diameter, and vice versa; 3. The judgments (values entered by experts) should be free of contradiction by calculating the consistency rate (CR), which is a measure of the expert's mistake or an indication of the degree of consistency or inconsistency [57]. If CR <10%, the pairs comparison matrix (PCM) is acceptable and the weights value is valid, otherwise in this case, some pairwise comparisons of the parameters require rearrangement, after which the cycle is followed several times until the point at which an optimal value of CR <0.10 can be obtained. It can be said that the fewer variables in one group, with the homogeneity of these variables with each other in this group and a good understanding of the problem by decision-makers, all improves the consistency index and thus Decision makers avoid re-evaluating the relative importance of pairs of comparison between factors [58]. In this study Expert choice version 11 software was used to analyze the data and obtain the weights of the factors, which saves effort and time, as well as ease of application, this can be summarized in four main steps, as follows: 1. Design the Comparison matrix of the main and sub-criteria as Table 5, Table 6, Table 7, Table 8, Table 9, and Table 10; 2. Open Expert choice software, then open a new file and give it a specific name and save it in the appropriate place on the computer, then the saved file is opened and determine Goal and below it the name of criteria or sub-criteria are entered;

Table 5. Comparison matrix of the main criteria

Criteria	Environment	Climate	Topography	Infrastructure	Operation
Environment	1	2	1	2	1
Climate	1/2	1	1/3	1/2	1
Topography	1	3	1	1/2	1
Infrastructure	1/2	2	2	1	1
Operation	1	1	1	1	1

Table 6. Comparison matrix of sub-criteria of environment

Sub-Criteria	Noise and pollution	Land cover
Noise and pollution	1	2
Land cover	0.5	1

Table 7. Comparison matrix of sub-criteria of climate

Sub-Criteria	P	T	CI	WS	AP	RH
Precipitation	1	1	0.5	0.5	1	0.5
Temperature	1	1	0.5	0.5	1	0.5
Clearness index	2	2	1	1	2	1
Wind speed	2	2	1	1	2	1
Atmosphere pressure	1	1	0.5	0.5	1	0.5
Relative humidity	2	2	1	1	2	1

Table 8. Comparison matrix of sub-criteria of topography

Sub-Criteria	Elevation	Slopes	Soil types	Water stream
Elevation	1	0.5	0.5	0.5
Slopes	2	1	1	0.5
Soil types	2	1	1	2
Water stream	2	2	0.5	1

Table 9. Comparison matrix of sub-criteria of infrastructure

Sub-Criteria	Roads	Water	Electricity
Roads	1	0.5	0.5
Water	2	1	1
Electricity	2	1	1

3. Select pairwise numerical comparison to enter the matrix values, noting that only the values above the main diagonal of the matrix are entered and the program automatically extracts the values below the main diagonal as shown in Fig. 9; 4. Select pairwise graphical comparison then properties derived from pairwise comparison by which the graph of the criteria ,as well as the weights are obtained with the value of consistency rate for each group of criteria under the main goal as in Fig. 10, Fig. 11, Fig. 12, Fig. 13, Fig. 14, and Fig. 15. Thus, the relative weights of the main and sub-criteria computed using AHP method can be seen in Table 11, in which the total weight of stage 3 is the product of multiplying the weight of stage 1 by the weight of stage 2.

Table 10. Comparison matrix of sub-criteria of operational

Sub-Criteria	Distance from oil wells and fields	Distance from refineries	Distance from lines of oil and gas	Distance from cities center
Distance from oil wells and fields	1	0.5	1	0.5
Distance from refineries	2	1	2	1
Distance from lines of oil and gas	1	0.5	1	0.5
Distance from cities center	2	1	2	1

Table 11. Main criteria, sub-criteria, and their relative weight computed by the AHP method

Stage1		Stage2		Stage3
Main criteria	Weight	Sub-criteria	Weight	Total Weight
Environment	0.254	Noise and pollution	0.67	0.170
		Land cover	0.33	0.084
Climate	0.117	Precipitation	0.111	0.013
		Temperature	0.111	0.013
		Clearness index	0.222	0.026
		Wind speed	0.222	0.026
		Atmosphere pressure	0.111	0.013
		Relative humidity	0.222	0.026
Topography	0.212	Elevation	0.136	0.029
		Slopes	0.237	0.050
		Soil types	0.340	0.072
		Water stream	0.287	0.061
Infrastructure	0.227	Roads	0.2	0.045
		Water	0.4	0.091
		Electricity	0.4	0.091
Operation	0.189	Distance from oil wells and fields	0.167	0.032
		Distance from refineries	0.333	0.063
		Distance from lines of oil and gas	0.167	0.032
		Distance from cities center	0.333	0.063
Total Weight				1

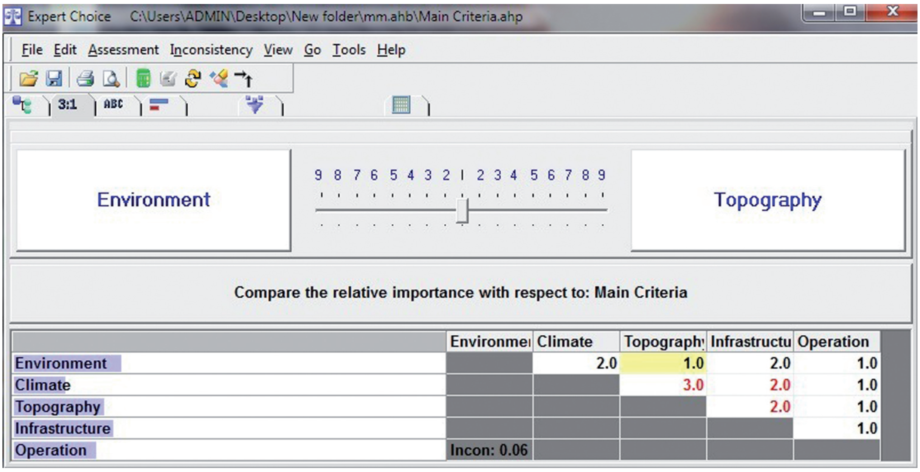

Fig. 9. The interface of the Expert choice software with entering the names and relative values of the criteria

Fig. 10. The relative weight and consistency ratio of main criteria by Expert choice software

Fig. 11. The relative weight and consistency ratio of sub-criteria of climate by Expert choice software

The integration between ArcGIS software 10.8 and AHP Method produces a suitability model and then produces the final output map, and this step is done by adding all the reclassified raster layers of criteria and overlaying all criteria weights obtained by the AHP method using the Weighted Sum feature which exist in Overlay box which is located within

Fig. 12. The relative weight and consistency ratio of sub-criteria of operational by Expert choice software

Fig. 13. The relative weight and consistency ratio of sub-criteria of infrastructure by Expert choice software

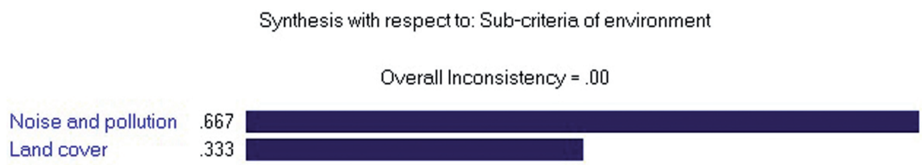

Fig. 14. The relative weight and consistency ratio of sub- criteria of the environment by Expert choice software

Fig. 15. The relative weight and consistency ratio of sub-criteria of topography by Expert choice software

Spatial Analyst Tools of Arc Toolbox, the final map is divided into 6 categories, starting with score 4 and ending with score 9, with a specific description of suitability including average-to-good suitability, good suitability, very good suitability, excellent suitability, and perfect suitability as shown in Fig. 16.

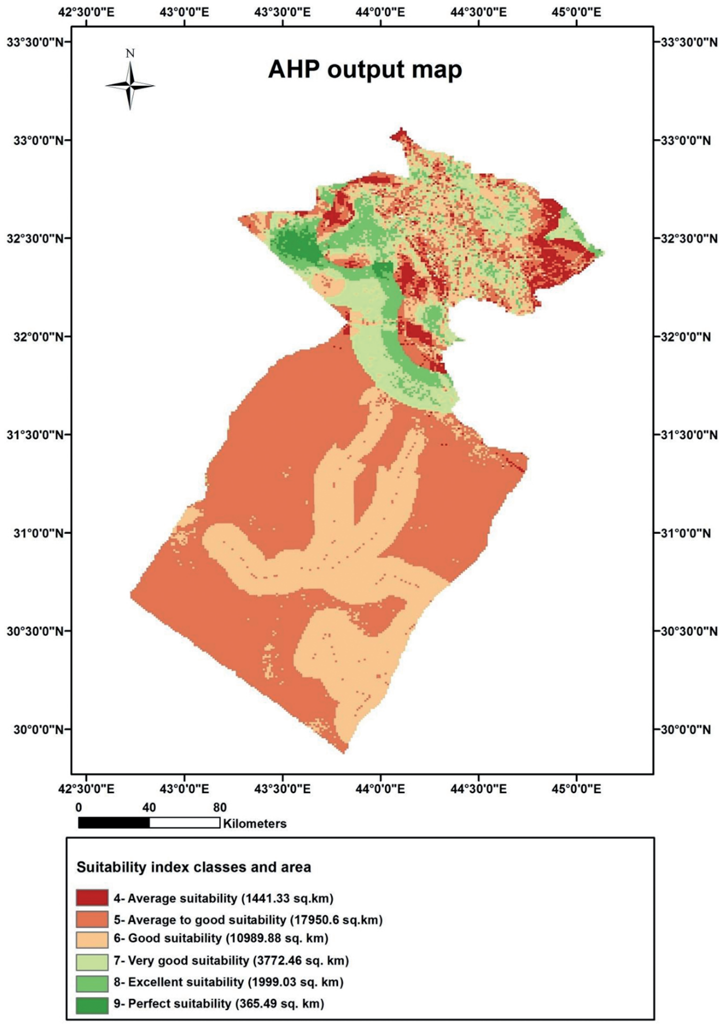

Fig. 16. Output map of applying the GIS–AHP method

6. Result and discussion

From the outputs of the suitability index, it was found that the output map represented in Fig. 16, which was obtained through the application of the AHP method, includes 6 classes of suitability index, and each class occupies a certain area of the study zone, where class 5 (average to good suitability) with an area of 17950 km^2, or about 49% of the total area of the study zone, followed by class 6 (good suitability) with 10989 km^2, 30% of the study zone, class 7 (very good suitability), 3772 km^2, 10% of the study zone, class 8 (excellent suitability), 1999 km^2, 5% of the study zone, class 4 (average suitability), 1441 km^2, 4%

of the study zone, and the last class 9 (perfect suitability), 365 km^2, which constitutes 1% of the total area of the study zone.

Through designing the suitability model using the ArcGIS software version 10.8 by adding the maps of the reclassified raster layers, each of them represents one of the criteria included in the selection of suitability for the airport within the multi-criteria decision method, and then overlaying the weights of the criteria obtained by AHP method, it turns out that there is an exceptional integration between the ArcGIS software and the AHP method, especially that there are specific boxes within the ArcGIS software to overlay the weights of criteria and its layers to obtain appropriate indicators, spatial or other depending on the type of study.

By projecting the location of the current and proposed airports in the study area and the outputs of the suitability index, it was found that the current location of Najaf International Airport and Karbala International Airport were fallen within category 7 (very good suitability), while it was found that the proposed location of Babylon International Airport falls within category 6 (good suitability), this indicates that there are obstacles in this area designated for the airport, as it is possible to change the proposed location of the airport until there are areas of category 7 and 8, in this province.

It is clear from the outputs of the suitability analysis, Fig. 16, that the percentage of suitable areas for constructing an airport represented by classes 7, 8, and 9 is 17% of the total area of the study zone, while the areas less suitable for constructing an airport constitute 83% of the study zone, represented by classes 4, 5, 6, where Karbala province occupies the first place in the proportion of suitable areas, followed by Najaf province and then Babylon in the last place. This result is due to Iraq's lack, especially within the scope of the study, of infrastructure services represented in the distribution of water, roads and electricity network, as well as the result of the random distribution of the population, especially in agricultural areas, and the absence of modern cities, which negatively affected the population factor as well as the land cover factor where all these factors are part of the 19 criteria selected to represent the scope of the study.

7. Conclusions

This research presents an integrated model that combines the AHP method, one of the multi-criteria decision analysis methods, and GIS technology, taking advantage of international environmental standards to obtain an effective and practical technique for analyzing the extent of spatial suitability, and thus choosing the best site for establishing an airport in the Middle Euphrates region in Iraq.

19 of the criteria included in the selection of airports were used in proportion to the scope of the study area, which are converted into layers within a series of operations by GIS technology, ending with overlay weight analysis process to analyze the spatial suitability for the establishment of an airport in the middle Euphrates region. These criteria were land cover, distance from residential areas, height above sea level, relative humidity, atmospheric pressure, wind speed, clarity index, temperature, precipitation, soil properties, the slope of the land surface, distance from streams, proximity to resources water, proximity to roads,

proximity to electric power lines, distance from oil wells and fields, distance from factories and oil refineries, distance from city centers and distance from oil and gas lines.

The weights of the criteria have been set by the AHP method, based on the salient features of the study area, regulations, applicable global rules, expert opinion, and literature review of previous research. The suitability map included six categories from 4 to 9, which are 4 (average suitability), 5 (average to good suitability), 6 (good suitability), 7 (very good suitability), 8 (excellent suitability), and 9 (perfect suitability).

There is a great agreement between the outputs of this study and reality, and this indicates the accuracy of the performance of the work of the model, which can be exported as an effective tool to support multi-criteria decision-makers.

The conclusions of the study zone can be summarized as follows:

1. There are no recent and accurate studies in Iraq related to evaluating the reality of aviation and airports, and there are no special determinants for the locations of international and local airports within a specific area, except for some planning determinants that revolve around the spatial expectation of the airport in a way that ensures easy access to it or ensures the safety of the urban centers it serves from aviation accidents.
2. The large size of the unsuitable area for the construction of airports, about 83% compared to the appropriate area, which is about 17%, and this are attributed to the lack of infrastructure services in Iraq, and in particular the study area, represented by road, electricity and water networks.
3. The land cover criterion indicates the appearance of large areas of barren land, offset by the appearance of a random expansion of the population around the main cities, and the absence of modern cities due to poor urban planning, which negatively affected the exit of large areas of land that could have been good sites for the construction of airports.
4. When interrupting the output map with the current and potential locations of the airports within the scope of the study, it turns out that the Najaf International Airport in the Najaf province and the Karbala International Airport in the Karbala province are within the appropriate areas for establishing airports, while the potential location of Babel International Airport is within the unsuitable areas for establishing Airports, and it is possible to change the proposed location of Babel Airport as long as there are suitable areas for establishing airports in the governorate, located in the far east of the governorate, as is clear on the map.

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