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INTEGRATION OF GIS AND REMOTE SENSING TECHNIQUE FOR HOSPITAL SITE SELECTION IN BAQUBA DISTRICT

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Abstract

Public health demands are rapidly increasing as the standard of living improves. The limited and unbalanced medical resources cause prominent community problems where site selection becomes a very important factor. Accordingly, construction of a new hospital with a rational allocation is a critical issue. In this respect, this study aims to find a potential site to build a new hospital in Baquba district/Diyala governorate using GIS-based multi-criteria analysis (MCA). Using spatial analysis, a set of criteria is used to identify potential sites for the hospital to be built considering a reliable location next to the main roads of the city. Additionally, the population factor is mainly included to locate a suitable location. The results show the feasibility of GIS-based MCA as a useful approach for decision makers to propose the best site selection. Furthermore, it is an effective tool for public administration to create the essential databases to perform spatial analysis. Interestingly, a suitability map is used in this study to identify the most suitable locations for the hospital. This in turn investigated possible sites that divided into three categories; excluded, low suitability and high suitability.

Keywords: GIS; Hospital; Multi criteria analysis, Remote sensing; Site selection.

1. Introduction

One of the vital elements of health infrastructure especially in developing countries is hospitals. The hospital's location plays an essential role in managing the hospital where selecting a suitable location could improve the allocation of medical resources. Additionally, it could reconcile the provision of healthcare with social and economic demands, but most importantly it could coordinate the development of urban and rural health services. An appropriate hospital location aids to access to healthcare, reduces rescue time and meets the medical needs of citizens, which entails a high-quality of life.

During the last few years, site selection has become a less complicated task for planners which assisted the development of Geographic Information System (GIS) and sophisticated computer technology [1]. In this respect, GIS provides various potential tools for decision makers to capture, manipulate, analyse, and manage spatial information. Determining suitable areas for land development is done using GIS. GIS combines computer technology with spatial and non-spatial database where it improves the planning's level and management's performance. Expectedly, this would have a great positive influence on achieving urban and regional planning [2, 3]. Solving the problem of multiple criteria without analytical and spatial tools can be a computational challenge [4]. Undoubtedly, GIS could be used to support spatial decision-making as it has good capabilities to deal with spatial issues. Interestingly, GIS-based multi-criteria analysis (MCA) has been considered as one of the most valuable methods for spatial planning [5, 6].

Several studies can be found in the open literature that used GIS-based Multi-Criteria Evaluation (MCE) for site selection and achieved reliable results [7-16]. However, other studies have combined the MCE with cost-benefit analysis [17]. The application of GIS technology eliminates vast amount of data and information, and also analyses data at a stage that helps to improve the efficiency of planning procedures. Based on hospital site selection, several studies employed GIS to settle hospital or health care research. For instance, Gordon and Womersley illustrated GIS advantages by using the map in public health and planning the health services [18]. Whereas, Maglogiannis and Hadjiefthymiades [19] combined the geographic information systems and location-based services of emergency medical incidents. This is intensively included the use of MCA to select and evaluate each option based on a specific set of criteria.

The novelty of this research is characterised by the employment of five criteria to identify appropriate locations to build a new hospital in Baquba / Diyala governorate, which are, existing hospitals, medical centres, rivers, roads, elevation, and population. These criteria were prepared as layers in ArcGIS 10.5 to create the site suitability map for the study area. The recent study demonstrates the capability of GIS-based MCA to help decision makers in health management. Additionally, it provides a scientific and worthy proposal to encourage the ministry of health to complete laws and regulations for the selection of a hospital's location.

2. Study Area

Baquba district is located in the Southern part of Diyala governorate and in the North-eastern part of Iraq (Fig. 1). It is situated between the latitude 33°- 35°N and the longitude 44°- 46°E, with an area of about 1,630 square kilometres. Its

estimated population is around 268866 people, according to census 2014, however in 2018 it reached a number of 631743 people [20]. This increase in population growth and lack of development of health sectors led to deterioration of medical services in the district. Administratively, the district composes of five areas (Baquba, Bani Saad, Buhraz, Kanaan, and Al-A'abarh).

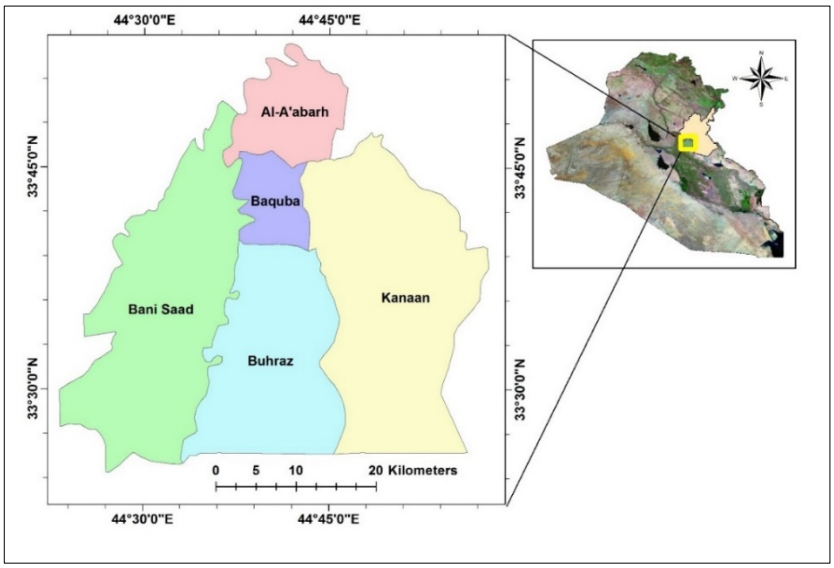

Fig. 1. Five districts of Diyala governorate and Baquba (studied area).

3. Methodology

GIS is one of the most reliable and widely used tools as a "decision-making tool" for spatially related matters in the modern world. The first step of the study focuses on evaluating existing hospitals and medical centres in the study area. This is attributed to the importance of identifying and analysing the current situation of exist hospitals and medical centres in the nominated area. The second step of the study focuses on analysing the collected data to select potential hospital's sites based on geospatial technology using ArcGIS Software. Figure 2 depicts the methodology used in the current study.

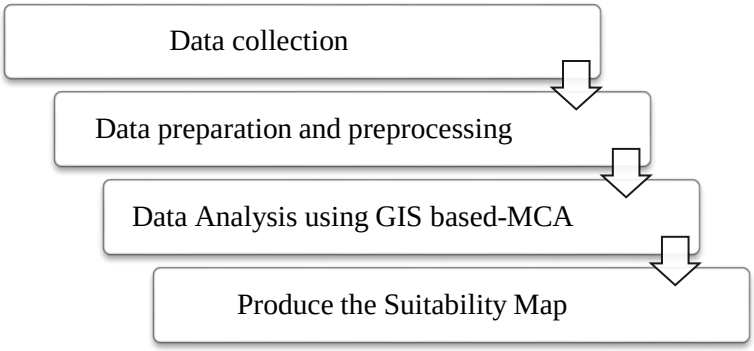

Fig. 2. Methodology steps of the current study.

3.1. Dataset

In this study, various dataset are used to prepare five selected criteria maps. The details of these datasets are discussed in the following paragraph.

3.1.1. Roads

Data about roads was collected from Diyala Directorate of Municipalities [21] as shown in Fig. 3. Using ArcGIS 10.5 software, the district border was used to clip the roads in order to limit the amount of data. Then, the data was projected in Universal Transverse Mercator (UTM) with geographic coordinate system on spheroid WGS 1984.

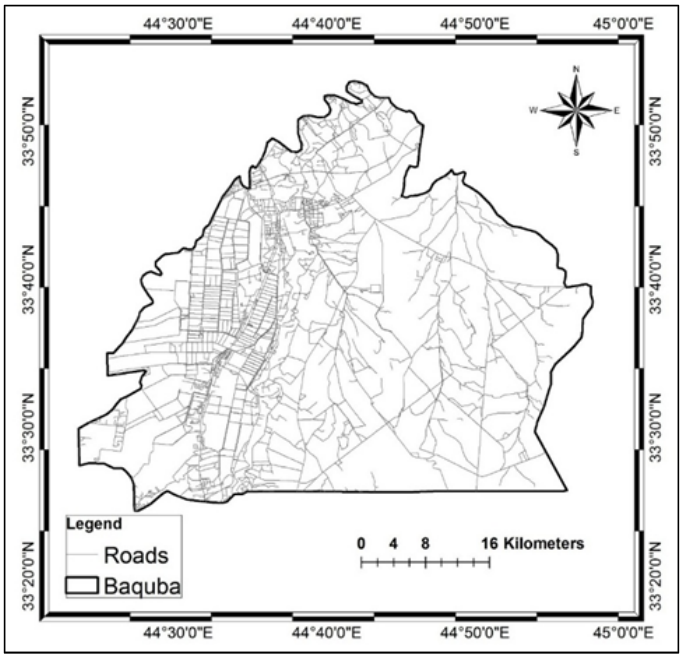

Fig. 3. Roads data for the studied area.

3.1.2. Elevation

Digital elevation model (DEM) offers variety of data that assist in producing the slope map [22]. The SRTM Version 3 DEM was used to drive the slope map of the studied area, with spatial resolution of 30 m as shown in Fig. 4.

3.1.3. Existing hospitals and medical centers

Data regarding existing hospitals and medical centres were collected from Diyala Health Bureau [23] and using GPS. Then, it was converted into Excel sheet to map, as shown in Fig. 5.

3.1.4. Population

The population of the city was collected from Diyala Directorate of Statistics [20]. The collected population data for Baquba district until the year of 2018 are presented in Fig. 6.

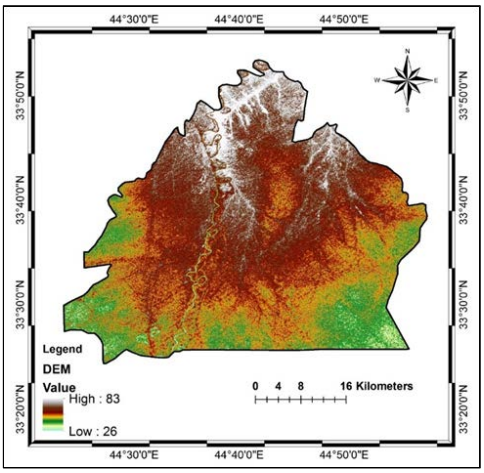

Fig. 4. DEM of the studied area.

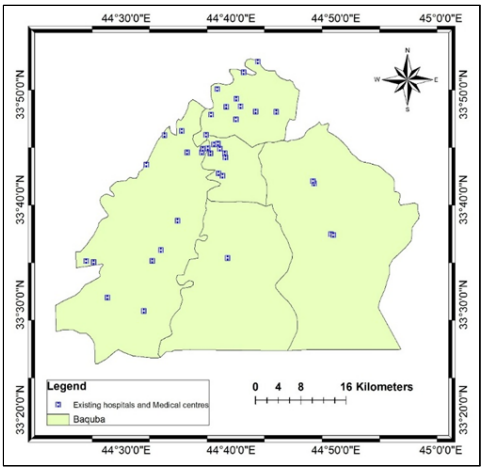

Fig. 5. Existing hospitals and medical centres.

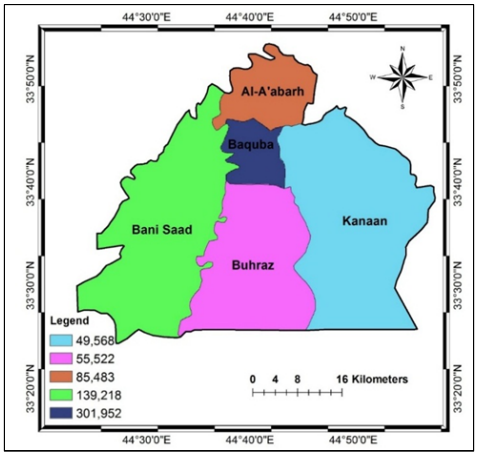

Fig. 6. The population's estimation data of Baquba district.

3.2. Factor criteria

The suitability map is created commonly using some of the map's criteria where; each criterion is shown on the map as a layer in the GIS software. Each map shows one criterion which is called a thematic layer [24]. Unfortunately, Iraq has no criterion standard for site selection analysis. Therefore, MCA is the new approach which is currently introduced for the first time for the nominated purpose of hospital site selection. It is noteworthy to mention that all the previous proposed criteria were developed by several researchers such as Ramzi and El-Bedawi [25], Wu and Zhou[26], Rahimi et al. [27] and Youzi, et al. [28]. Additionally, equal weight are assumed for the proposed criteria. This study focuses on GIS-based-MCA capability in the hospital site suitability analysis. This is specifically included the suggestion of five criteria and constraints. However, these may change according to the experts' and decision-makers options. Five layers (road, river, existing hospitals and medical centre, population, and slope) are overlaid and ranked based on significant site selection. The weights and the values of the criteria can be changed according to the characteristics of the study area and experts' opinions [29]. According to experts' opinions, the criteria for a new hospital location used in this study are listed below:

i. Existing hospitals and medical centres: Keeping a distance from other existing hospitals and medical centres should be an essential factor. A distance of 500 m between the new hospital site and existing ones and medical centres is suggested (the farthest location is best).
ii. Roads: Hospitals must be located near the roads. Therefore, the closer thelocation to the roads the better. A distance of 200 meters is set. At outside the buffer zone, the nearest location is the best.
iii. River: If the new hospital's sewage drains into the river, a minimum of 300 meters along the river should be used. Outside the buffer zone, the further away the location from the river the best.
iv. Population: The population factor was also comprehended to choose a suitable location for the hospital.
v. Slope: The site should be on a relatively flat land. The slope map was derived from SRTMV.3 DEM with spatial resolution of 30 m.

Table 1 presents the datasets used in the above analysis.

Table 1. The factor criteria layers setting.

Criteria	Setting
Existing hospitals and medical centres	Maximisation, the farthest the best, suggested distance of more than 500 m.
Road	Minimisation, the nearest the best, suggested distance of less than 200 m.
River	Maximisation, the farthest the best, suggested distance of more than 300 m.
Slope	Minimisation, less than 10 %.
Population	Maximisation.

3.3. GIS-based multi-criteria analysis

ESRI characterises GIS as "a composed package of PC equipment, programming, geographic information, and workforce. These intend to efficiently catch, store,

update, control, investigate, and show all types of the geographically referenced data. In the recent decades of an internet availability, GIS was widely engaged in people's daily life to find the best location [30]. The digital maps with GIS techniques are easy to use and save time and cost [31]. This is basically based on traditional methods of GIS based on the processing of effective layers into a classified map, such as utilising a Boolean model [32] or Index Overlay processes [33, 34].

Interestingly, MCA is a procedure that usually combines conflicted criteria necessary for evaluation and decision-making. It has a broad application in our life and in professional uses. Yassine and Adel stated that the principal of the MCA is to condense complex problems with multiple criteria into a finest ranking of the best scenarios from which an option can be selected [35]. The criteria are weighted according to their importance, and their weights have a more or less favourable on the final decision than another [36]. GIS-based MCA involves two essential sections: factor criteria and constraint criteria. Each of these criteria is represented as a map layer [36]. As for the weighted summations procedures, the weighted linear combination of factor criteria is shown in Eq. (1) [37].

$$s = \sum w_i . f_i \tag{1}$$

where s, w_i and f_i are the suitability to the objective being considered, the factor weigh, and the criteria score of factor *i*.

4. Results and Discussion

The pre-**processing** of the dataset is the final step that used to reclassify the layers and to make them ready for the suitability process. In this respect, Arc GIS 10.5 was used to integrate all the layers into one map using the overlay process. The following sections present several contributions of the recent study with a brief discussion.

4.1. Criteria layers

In this study, various criteria are used to locate hospital's location. The criteria are discussed in the following paragraph.

4.1.1. Existing hospitals and medical centres

Proximity to the existing hospitals and the medical centres is the most important criterion in site selection. In accordance with rational resource allocation, the new hospital location should be at a suitable distance from the existing hospitals and medical centres. The distance is determined by using the Euclidean distance, which is referred to a straight-line distance between points, as established in the Cartesian method shown in Fig. 7.

4.1.2. Distance to Roads

Another important factor in site selection is access to roads. A straight-line distance calculation is made on the roads using Arc GIS to obtain a representation of roads' importance. The distance from the main road is determined in meters using the Euclidean distance as shown in Fig. 8.

4.1.3. River

A straight line distance calculation is made on the river by using ArcGIS. The distance from the river in meters is determined by using the Euclidean distance as shown in Fig. 9. The furthest the better, with a suggested distance of more than 300 m.

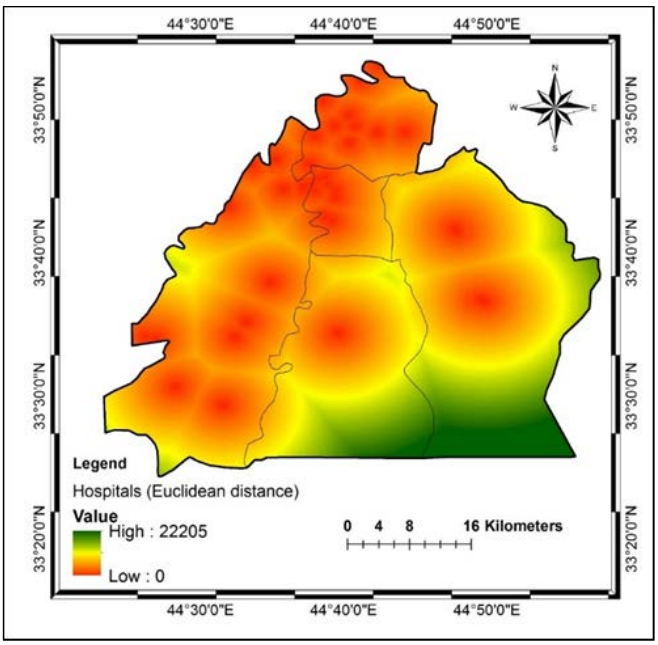

Fig. 7. The Euclidean distance from hospitals.

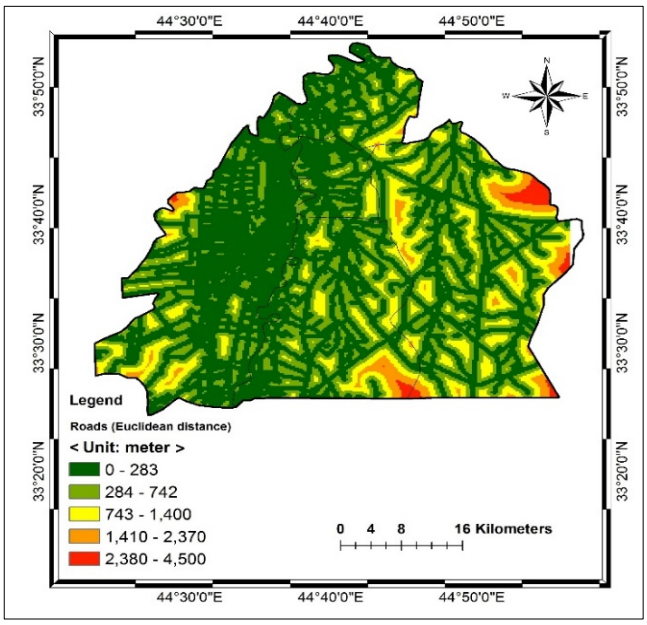

Fig. 8. The Euclidean distance from the roads.

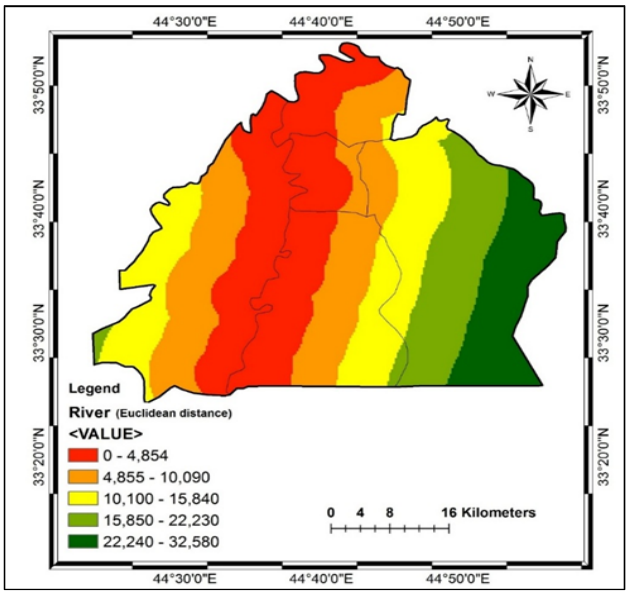

Fig. 9. The Euclidean distance from the river.

4.1.4. Slope

The overall slope of the site must be flat enough to allow easy construction. The suggested slope in this study is less than 10%. The terrain is defined with extreme conditions in the temporary hospital setting as higher than 10%. These areas are given a value of zero. All other regions are given a value of one. This steep elevation with above 10 % elevation is seen as a constriction and given a value of zero to rule them out. The study area's slopes are shown in Fig. 10.

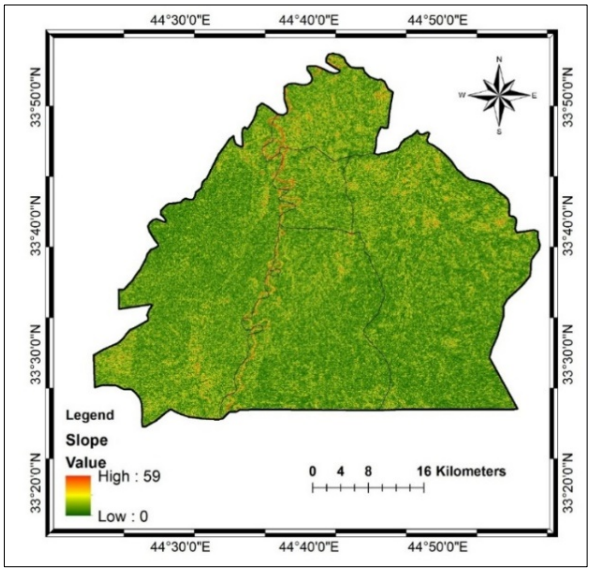

Fig. 10. The slope map of the study area.

4.1.5. Population

The hospital's location should be convenient for citizens to afford. Therefore, the population distribution is an important criterion as shown in Fig. 11.

4.2. Overlay processing

The overlay tool in ArcGIS 10.5 was used to multiply the criteria layers raster. Each layer in the final map has been reclassified to integer values instead of ranges to be used as inputs in the model. A value of one was assigned to the most suitable range and zero to the least suitable range as shown in Fig. 11. Finally, the study area was divided according to the proposed criteria to three classes: excluded, low suitability, and high suitability as shown in Figs. 12 and 13.

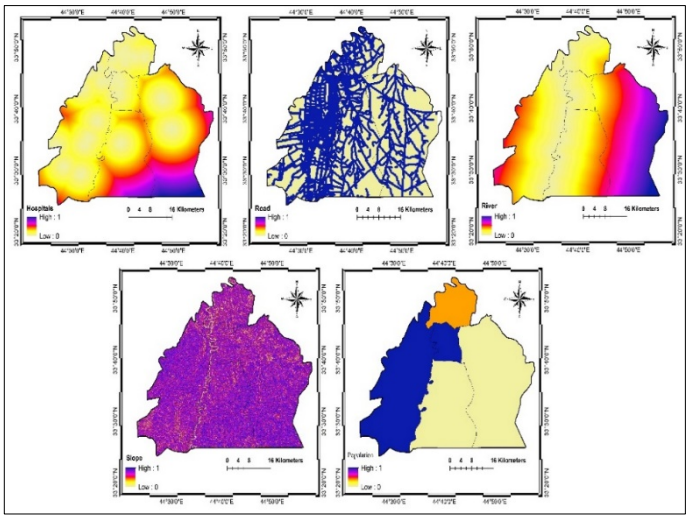

Fig. 11. The Standardized criteria layer.

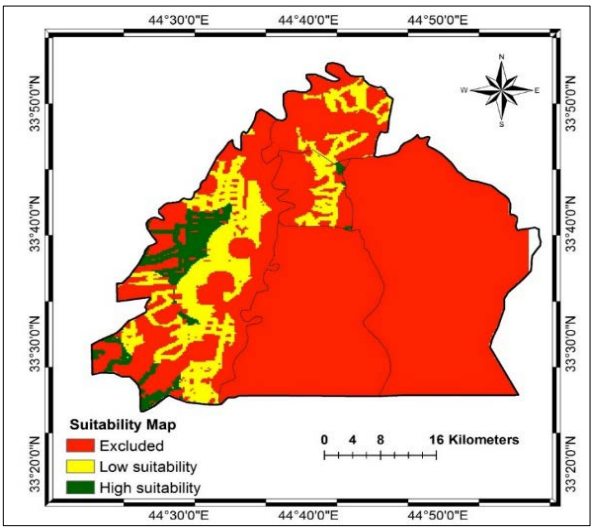

Fig. 12. The Final suitability map.

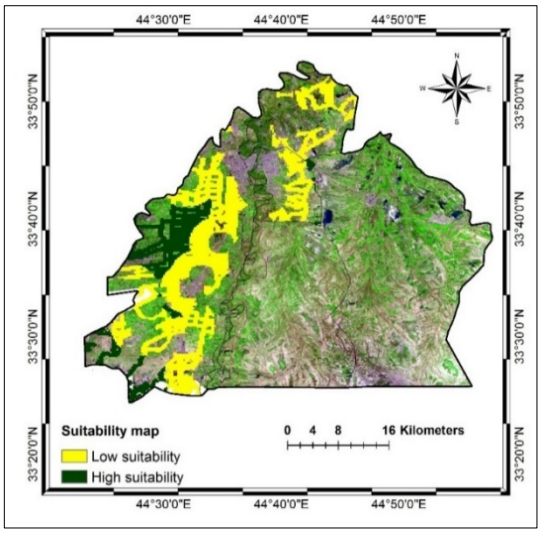

Fig. 13. The suitability classes dropped on the Landsat 8 image.

5. Conclusion

The GIS is a significant tool to analyse maps and visualise spatially related data that assists planners and administrators to make accurate decisions.

The current study implemented the GIS- based MCA to select a feasible site of a new hospital in Baquba District/ Diyala.

Basically, the study analysed different possible sites that divided into three categories; excluded, low suitability and high suitability. Interestingly, the study identified the most suitable hospital location by investigating several factors such as existing hospitals and medical centres, distance to roads, river, slope and population size.

This in turn would increase the opportunity to access health facilities by the society. Moreover, the study affirmed the successfulness of GIS technology as a primitive technique to estimate an appropriate location for nominated applications.

Nomenclatures

f_i	Criteria score of factor *i*
s	The suitability to the objective being considered
w_i	Factor weight

Abbreviations

GIS	Geographic information system
MCA	Multi Criteria Analysis
WGS	World Geodetic System
SRTM	Shuttle Radar Topography Mission
DEM	Digital Elevation Model
GPS	Global Positioning System
ESRI	An international supplier of geographic information system
PC	Personal Computer

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