

## **Multi-Criteria Decision Analysis for Primary School Site Selection in Al-Mahaweel district Using GIS Technique**

**تحليل القرار متعدد المعايير لاختيار مواقع المدارس الابتدائية في قضاء المحاول باستخدام تقنية نظم المعلومات الجغرافية**

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### **Abstract**

Site selection is the process of finding sites that meet the requirements set by the selection criteria. The long-term and success sustainability of planning school, finding the appropriate school locations is challenging and an important. This study aims to develop a primary school site selection model using Geographic Information Systems (GIS) integrated new approach. It was carried out by Geographic Information Systems and multi-criteria evaluation model (MCEM). Different criteria were used to suggest a number of potential primary school sites using a spatial analysis, which is the new school should be away from existing schools and the major roads, a new site should also be reliably flat land and on certain types of land use. The population factor of the age group less than 14 years was included as a factor to choose the suitable location. As a result, the final suitability map indicates that 18 % of the study area is suitable for a primary school site, 73% moderately suitable, and 9% of the study area under unsuitable.

**Keywords:** Selection site, GIS, Multi-criteria (MC) and Spatial analysis model.

### **الخلاصة**

اختيار الموقع الأفضل هي عملية العثور على المواقع التي تستوفي الشروط المطلوبة حسب معايير اختيار محددة. ولضمان نجاح التخطيط المدرسي واستدامته على المدى الطويل فإن إيجاد مواقع مناسبة لإنشاء مدرسة أمر مهم وصعب. تهدف الدراسة إلى تطوير نموذج اختيار مواقع مدارس ابتدائية باستخدام نهج جديد متكامل في نظم المعلومات الجغرافية ونموذج التقييم متعدد المعايير. تم استخدام مجموعة من المعايير لتحديد عدد من المواقع المحتملة باستخدام التحليل المكاني وهي: أن تكون المواقع بعيدة عن المدارس الموجودة والطرق الرئيسية، إضافة إلى ذلك أن تكون على أرض مستوية نسبياً وعلى أنواع معينة من استعمالات الأراضي. كما تم أدرج عامل السكان في الفئة العمرية التي تقل عن 14 سنة كعامل مؤثر لاختيار الموقع المناسب. ونتيجة لذلك فإن خارطة الملاءمة النهائية تشير إلى أن 18% من منطقة الدراسة مناسبة لموقع مدرسة ابتدائية، و73% مناسبة بشكل متوسط، و9% من مساحة الدراسة غير مناسبة.

**الكلمات المفتاحية:** اختيار الموقع، نظم المعلومات الجغرافية، متعدد المعايير ونموذج التحليل المكاني.

### **Introduction**

In the context of Multi-Criteria Decision Analysis (MCDA), this is facilitated by a selection and evaluating each option on a number of criteria. These criteria should be measurable, their outcomes should be measured for each alternative decision. Graphical Information Systems (GIS) used to support spatial decision-making (SDM) because it has capabilities to deal with spatial issues. The computational challenge is to solve a multiple criteria problem without visualization and spatial analysis tools [1]. As GIS-based MCDA considered one of the most useful techniques for spatial planning and management [2]. The request for tools supporting collaborative decisions has spiralled over the last decade [3]. Strategies with the Multi-criteria decision making as an independent tool have been computerized towards the extent that lots of software could be accessed and utilized [1]. However, it is unusual that such type of software programs to be able to deal with the spatial problem within the form of maps. There exist two strategies: loose and tight, for coupling of GIS with MCDA techniques [4]. In the loose coupling, it depends upon a file exchange

mechanism that provides an interface between the two types of the software program to connect. Likewise, individual tasks are performed in both software programs. In performing land suitability analysis, choosing a set of criteria with their scores to ensure that the choice table can be exported into MCDA plan, GIS is utilized.

In this paper, a decision-making process framework developed to produce primary school site suitability map. Road, Digital Elevation Model (DEM), built-up areas and population were prepared as layers in ArcGIS 10.2 to create suitability model using Model-Builder for the study area.

### **Study Area**

The study area includes Al-Mahaweel district (illustrated in figure 1) which lies within Babil province between longitudes (45° 6' 40"- 44° 20' 50" E) and latitude (32° 49' 20"- 32° 25' 20" N), which represents the eastern and northeastern part of the province [5]. Al-Mahaweel Center is located 20 km north of Hilla city and 80 km from Baghdad. The total area is 1667 Km<sup>2</sup>, which equals 33% of the total area of Babil province that is 5119 Km<sup>2</sup> [6]. The district structure consists of four administrative units; Mahaweel and its three aspects are (Al Mashru', Al Imam and An Nil).

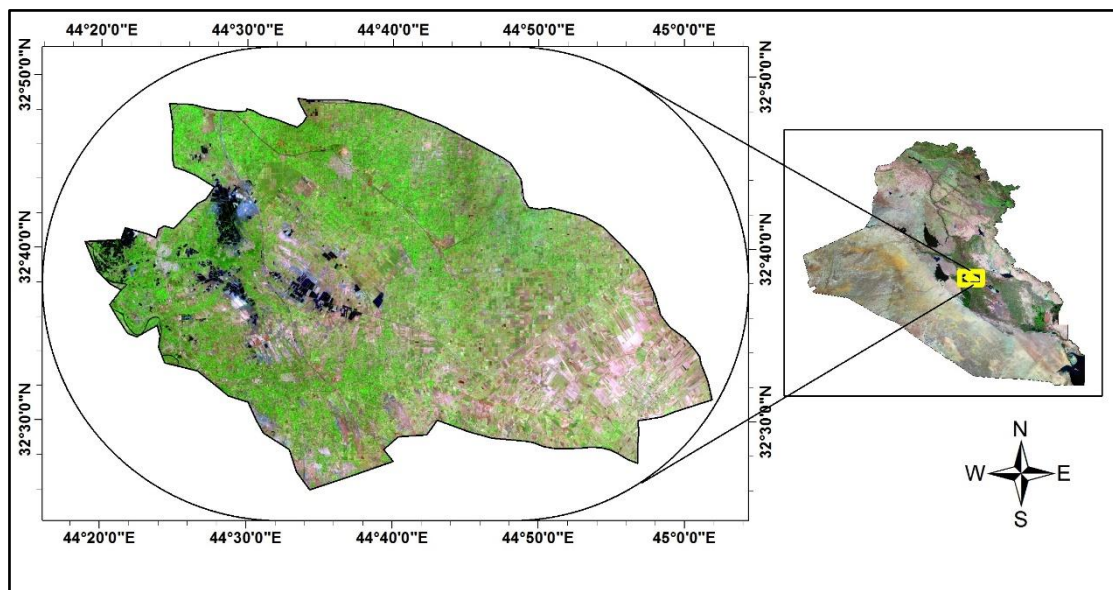


Figure 1: location of the study area (Landsat 8 Image-2017).

### **Methodology**

The GIS is the most widely and reliably used decision-making tool for the spatially related matters in the modern world. The first step of the study focuses to evaluate the existing primary schools in the study area. It was most important to identify and analyze the current situation of the resource allocation to schools and the school education planning system in the area. Second step was analyzing collected data in order to select the potential school sites based on geospatial technology using the ArcGIS Software tools. Next, the model was applied to determine the suitable primary school sites in the study area. The following figure (Fig. 2) illustrates the methodology for the study.

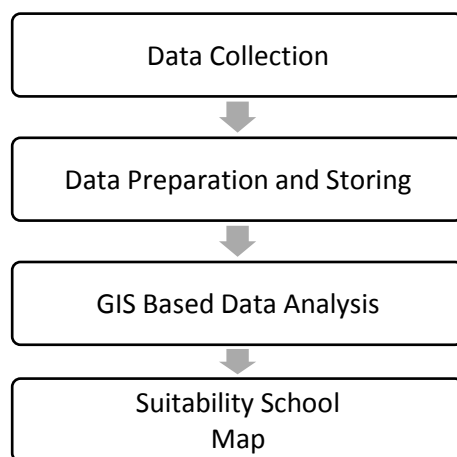


Figure 2: Methodological stages of the study.

**Maps of Criterion**

Criterion maps form an output regarding evaluation criteria identification stage. This follows input the data into Geographic Information Systems (acquisition, conversion, re-formatting, geo-referencing and documenting related data) saved in graphical and tabular type, manipulated and analyzed to obtain desired information. Generally, the suitability map is created using a number of criterion maps; in GIS each criterion is represented on the map as a layer. Each map represents one criterion and it's defined as a thematic layer [7]. They signify in what way the attributes are distributed in space and how they assist in achieving the objectives. In other words, a layer represents a set of alternative places for a decision. School mapping techniques used to ensure more rationalized distribution of schools with secured access to all children. The school suitability map would be produced using the GIS, Four layers (road, existing primary schools, population, and slope) were overlaid and ranking based on significant of site selection. The weights and the values of the criteria can be changed according to the characteristics of the study area and expert opinions [8]. The criteria for a new school location are listed below (Table 1 illustrate the datasets used in the analysis)

1. The new school should be away from existing schools (Fig. 3).
2. The site should be on relatively flat land (Fig.4), and on certain types of land use (Fig.5).
3. The new school should be away from the major roads.
4. The population factor of the age group less than 14 years was included as a factor to choose the suitable location (Table 2).

Table 1: Datasets used in the analysis.

| Criteria                  | Description                                       | Dataset Name                               | Value        |
|---------------------------|---|--|--------------|
| Slope                     | Slope, derived from SRTMV.3 Resolution 1 Arc sec) | DEM  | Minimization |
| Major roads               | highways  | Polyline feature class of the road network | Maximization |
| People less than 14 years | Number of people under the age of 14              | Population                                 | Maximization |
| Existing schools          | Location of primary schools.                      | Point feature class                        | Maximization |

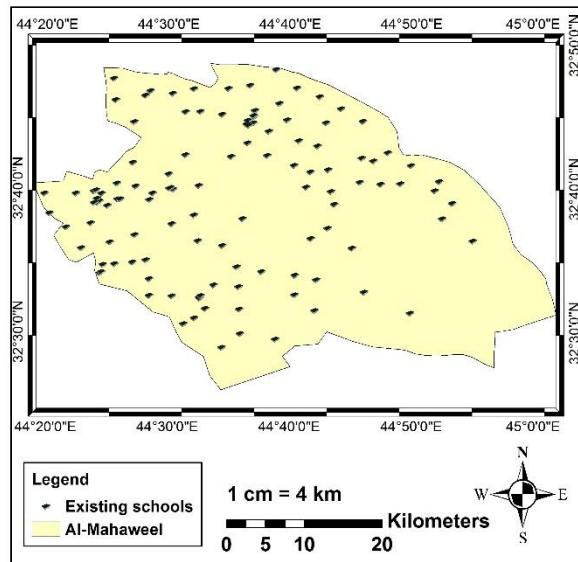


Figure 3: Existing primary schools.

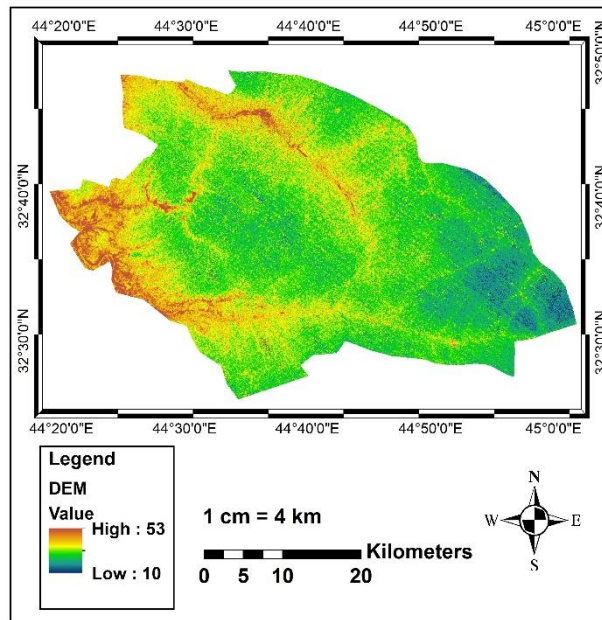


Figure 4: Study area DEM.

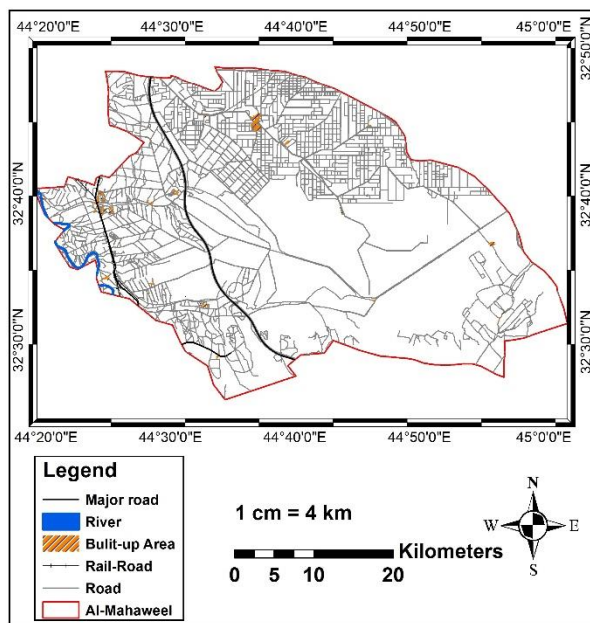


Figure 5: Land use Map.

Table 2: Age Categories [9]

| Age Categories | Al Imam |       | Al Mashru' |       | An Nil |       | Mahaweel |       |
|----------------|---------|-------|------------|-------|--------|-------|----------|-------|
|                | Boys    | Girls | Boys       | Girls | Boys   | Girls | Boys     | Girls |
| 0 – 4          | 3418    | 3286  | 11741      | 1295  | 5565   | 5369  | 10976    | 10567 |
| 5 – 9          | 2866    | 2756  | 9846       | 9472  | 4667   | 4502  | 9204     | 8861  |
| 0 – 14         | 2429    | 2375  | 8345       | 8165  | 3956   | 3881  | 7802     | 7638  |
| Total          | 17130   |       | 58864      |       | 27940  |       | 55048    |       |

### Assigning Weights

Manipulation and reclassification is required for all data integrated into the spatial database to create a standard scoring technique [10]. A "Suitability Weighted Model" developed using GIS depending on a number of criteria layers [11]. This can be interpreted by equation 1 (Shirahatti et al, 2010).

$$Su = \sum w_f x_f \quad \dots (1)$$

Where,

$w_f$  = Factor weight.

$x_f$  = Criteria class score.

Su = Suitability index.

For each pixel in the final map the total weights can be derived from the following equation:

$$S = (AP_f AP_c + AE_f AE_c + AR_f AR_c + AS_f AS_c) \quad \dots (2)$$

Where,

S is dimensionless for new school location index in the final integration map.

AP is the population less than 14 years.

AE is the Existing primary school.

AR is the major road.

In addition, AS is the slop.

The subscript letter 'f' represents the weight of each factor, while 'c' represents the weight of each class of the individual factor.

### Results and Dissections

In this paper, the weights assigned for each layer are (0.35, 0.25, 0.20, and 0.20) for existing school, population less 14 years, major roads, and slopes respectively.

**Existing primary school**

Proximity to the existing school is the most important criterion for the new school site selection. In accordance with rational resource allocation, the new school location should be at a suitable distance from the existing primary school. The distance determines using the Euclidean distance that is referred to a straight-line distance between points, as established in the Cartesian method (Fig.6)

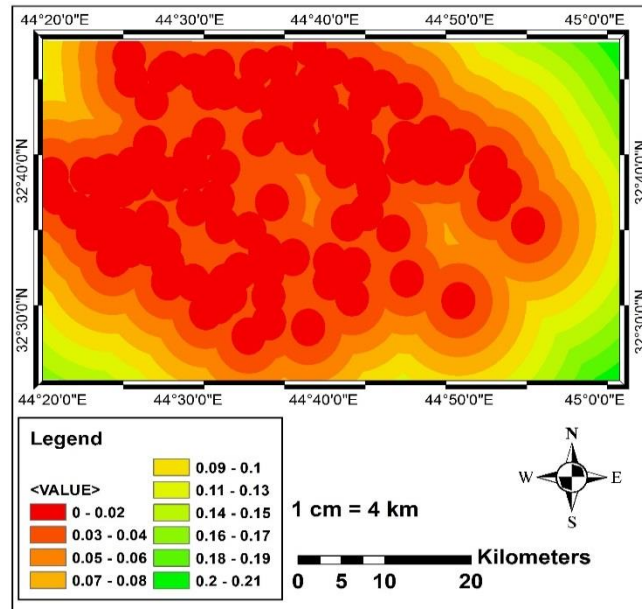


Figure 6: Euclidean Distance from schools.

**Slope**

The overall slope of the site must be flat enough to allow for ease of construction. To build on, a flat terrain is the least expensive and easiest. On the contrary, a rolling or sloping terrain is more difficult and more expensive for construction. Using the natural ground slope, the drainage and sewage disposal systems can be designed to result in lower construction and maintenance cost. The study area slop shown in Figure 7.

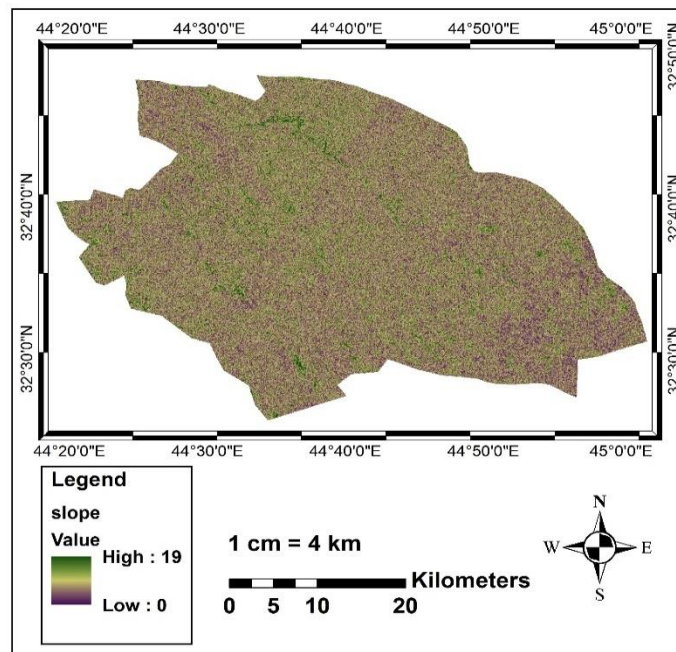


Figure 7: Study area Slope.

**Proximity to major roads**

Another important factor in site selection is access to roads where the site must not be adjacent to a major road. Any site-related traffic and sound level will have safety problems or sound levels that adversely affect the educational program. However, we must not overlook the fact that the school should be located in an area that would reduce the commute time to the school for parents and students. The distance from the major road determines using the Euclidean distance (Fig.8).

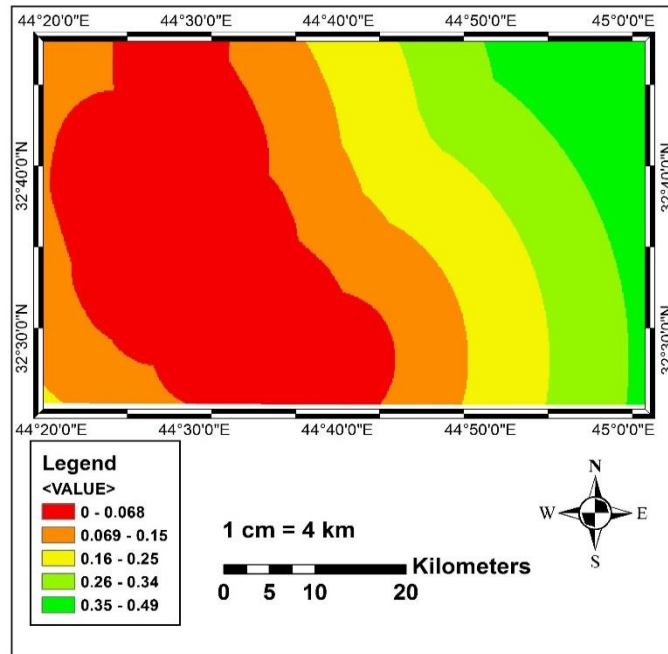


Figure 8: Euclidean Distance from major roads.

**Population under 14 years- old**

Schools should be conveniently located for the student populations they serve; therefore, the population distribution is an important criterion. It should be closer to the residential areas with a higher population under 14 years-old (Fig. 9).

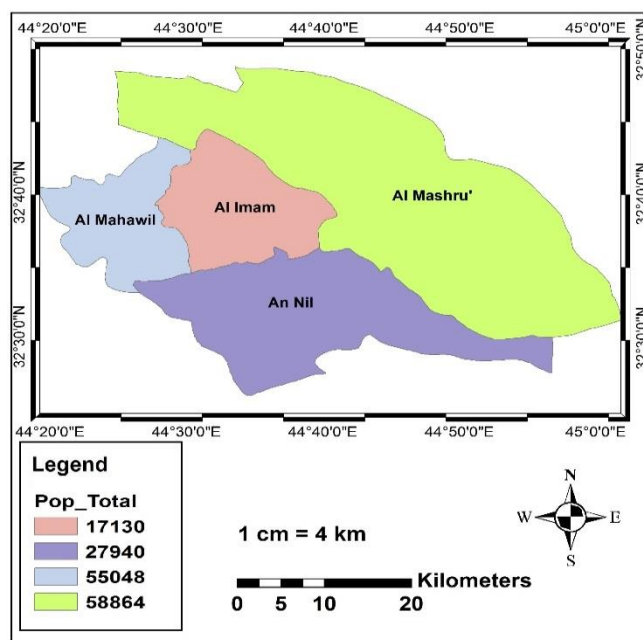


Figure 9: Population less than 14 years.

Each layer in the final map has been reclassified to integer values instead of ranges to be used as inputs in the weighted model. A value of one was assigned to the most suitable range and five to the least suitable range (Figure 10).

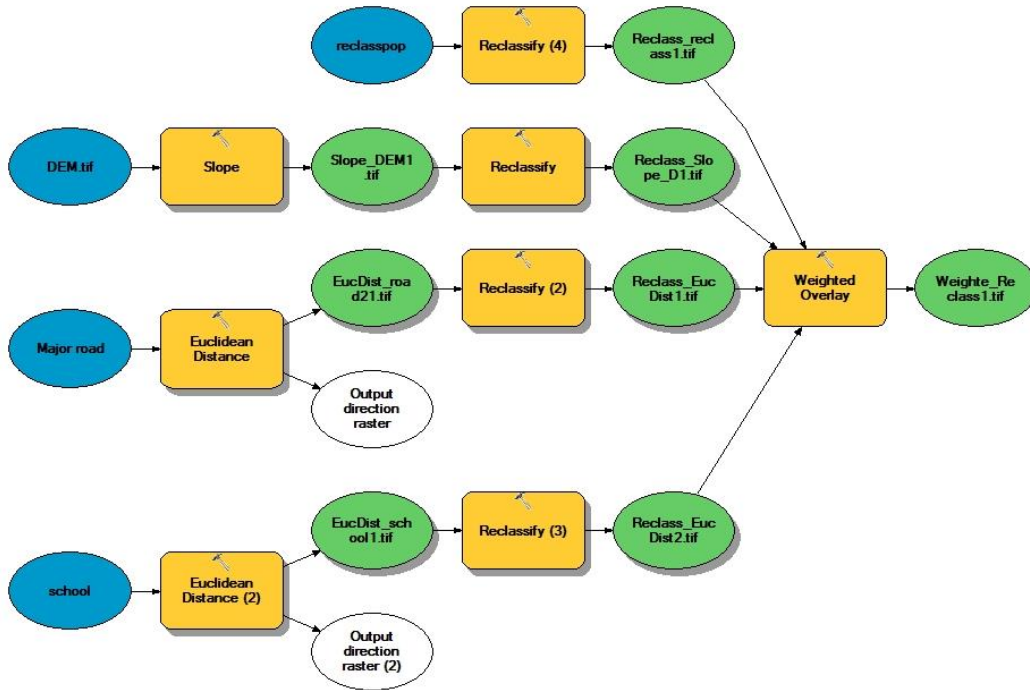


Figure 10: The model using model builder.

The study area divides according to the proposed criteria and weights to three classes good, medium and bad as shown in figure 11.

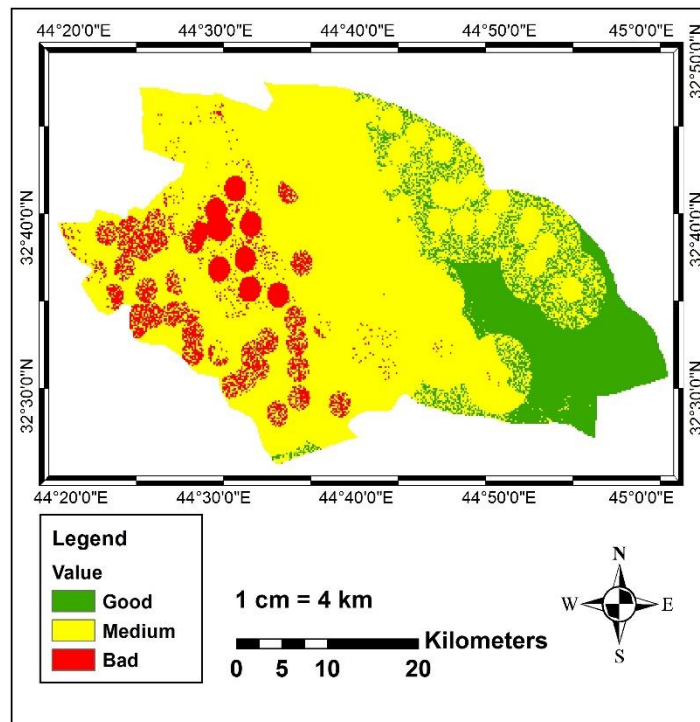


Figure 11: Final suitability Map.

## **Conclusion**

- The GIS is a significant tool for Analysis, Mapping, and Visualization of spatially related data. The GIS-based multi-criteria analysis special analytical method has been used to develop the school site selection model that is presented in this research.
- The study and its result illustrate the successful implementation and advantages of applying the GIS technology for education planning and decision-making process. The use of GIS technology based modelling for decision support system has created new capabilities and advance assistance to the planning process.
- GIS is not only an analytical tool but also a tool to assist planners and administrators to make decisions and it is realizing the ground reality visually. Therefore, GIS-based analytical technology has strong possibilities to provide the sustainable solution for spatially related problems. Hence, the research is capable to increase the opportunity of access and the quality of education facility of the society.
- As a result, it was possible to identify most suitable for locating schools in the area. Where the study area divides according to the proposed criteria and weights to three classes good, medium and bad.
- The final suitability map indicates that 18 % (302.1 Km<sup>2</sup>) of the study area is suitable (good location) for a primary school site, 73% (1245.5 Km<sup>2</sup>) moderately suitable, and 9% (149.7 Km<sup>2</sup>) of the study area under unsuitable (Bad).

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