An allocation model based on Fuzzy logic and ANN for establishing recreational centers, case study: Hilla, Iraq

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Abstract

Recreational sites are considered a vital part of urban activities in cities. They contribute to strengthening social ties and provides possibilities for change in behaviour, attitudes and, customs, and creating new concepts. In this paper, an effective model based on fuzzy logic and Artificial Neural Networks (ANN) has been proposed for recreational allocation in Hilla. The efficiency of recreational facilities depends on their geospatial distribution and it should be considered in the allocation phase. The proposed models were designed on the population density and the distance to built-up areas, roads, green areas, railway and, water bodies. The results showed that the fuzzy model outperformed the ANN model. On the other hand, its implementation cost was much less than the ANN algorithm. The proposed allocation model could provide valuable information for managers when locating recreational facilities in Hilla and can be prevented from the waste of national resources in sustainable cities.

Keywords: Recreational site selection, human health, fuzzy logic, ANN

1. Introduction

The planning and development of recreational services is a civilizational [1], cultural and entertaining phenomenon for the benefit of the entertainment community in particular and society in general. This phenomenon is strictly dependent on the regional and international levels and also depends on modern scientific methods. This phenomenon will enrich the human psyche with its aim of entertainment, relaxation and meditation in light of conditions characterized by a large increase in the size of the population and high level of civilization cultural and pension [2]. This will result in a significant increase in entertainment demand on the one hand and a decrease and sometimes the lack of entertainment services on the other hand in the city of Hilla in particular and Iraq in general. Today, after the growth in Hilla city population, governmental agencies plan to provide recreational services commensurate with population growth. by using geospatial information systems (GIS) [3]. In light of the above, this study seeks to propose the best sites for establishing recreational services using GIS according to the standards green area, population and youth in each region [4]. Several researches were conducted to find suitable locations for various infrastructures based on different techniques such as statistical, artificial intelligence, fuzzy logic, Analytical Hierarchy Process methods. The suitability analysis literature indicated that ANN method has been successfully used in a finding suitable locations based on various criteria, such as the selection of best location for convenience store, historical development [5],[6]. On the other hand, the Fuzzy logic method is one type of frequently used method in the suitability location analysis. It set a membership value to the resulted locations ranged between 0 and 1, which 0 value refers to unsuitable or non-membership and 1 value indicates a suitable site or membership. Several studies conducted to find suitable locations by using Fuzzy logic [7].

2. Literature review

Jasim et. all, indicated the laying of the planning foundations for the development of recreational services in Lake Jadiriyah, south of Baghdad. Where they showed that the factor of recreational attraction in the lake, the size of the increasing demand in the city and the result of the population growth experienced by the seekers of entertainment are important factors and drivers for the development of recreational places. They studied the existing services based on the study, field tours and questionnaire (200 questionnaires with 41 questions) that were distributed to a sample of visitors during the peak season. Through graphical analysis, several stages were proposed to develop future entertainment services in line with the desires and aspirations of the hikers[4].

Abdullah et. all, aimed to assess the reality of recreational services in the city of Hilla, its spatial distribution, and the area it occupies, to identify the factors affecting its distribution, as well as to identify the efficiency of recreational services[8]. They used several data sources such as field surveying (questionnaire), maps, and statistical information with calculation of services efficiency based on urban planning standards, accessibility, and population satisfaction. Their study concluded that the city lacks recreational locations. In addition, the existing recreational sites were established without consideration standards that related to urban growth.

Ahmed et. al, was interested in developing recreational elements, activities and events on the Tourist Wedding Island[9]. Where the region represents a large green area, however, it suffers from a decrease in the volume of entertainment services and does not meet the entertainment demand. The researcher's goal was to expand and diversify recreational services to meet the needs of hikers and reach their satisfaction. The researchers concluded that in fact the city is endowed with and but it is suffered from a lack of interest in it and the lack of future plans for its development and investment.

Abdullah et. al, studied the distribution of recreational services in the city of Baghdad in order to get acquainted with the types of services available to satisfy the needs of the residents in that city[10]. In general, Baghdad city is missing the existence of a future plan to develop recreational sites. They also submitted a proposal to redistribute the services in line with the approved planning standards. The researchers are relied on descriptive and analytical methods to identify the nature of data. Moreover, they used GIS for analysis with the standard distance. The researchers concluded that the urban city is suffering from negligence and shortage of recreational facilities. In addition, the city is suffering from green space overrun.

Pradhan et. al, proposed a model based on the integration of Fuzzy logic and GIS modeling to find a suitable camp location for refuges in Al-anbar, Iraq. The results showed that a suitable location for camp is located near the city of Falluja[11].

The lack of recreational sites in Al-Hilla city prompted us to investigate this problem. We applied fuzzy logic and ANN to find suitable locations for establishing recreational sites in the center of Hilla city.

3. Methodology and Data

3.1. Study area

Al-Hilla represents the city center of Babylon governorate in Iraq. It is located between 44° 22’ 12.426” – 44° 22’ 12.554” E and 32° 24’ 23.54” – 32° 31’ 57.4767” N. Figure 1 shows the map and the geographical area of Al-Hillah city. It covers an area of about 161 km2 with a population of about 465,524 [12]. This area is characterized by several types of land use such as commercial, industrial, residential areas and several human activities and infrastructures that recently increased. Moreover, there are many archeological sites such as old Babylon city distributed near the city making this area a tourist attraction location. On the other hand, agricultural lands covered high areas in Babylon province [13]. The weather in this area considered cold in winter and hot-dry in summer.

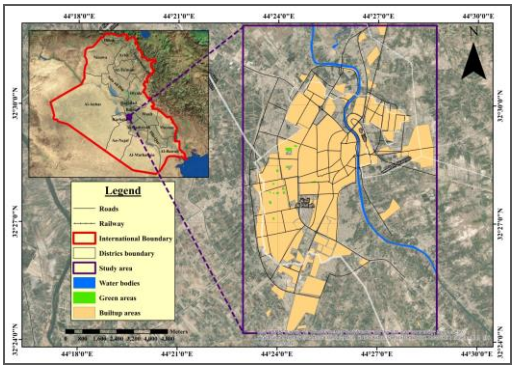

Figure 1. Land use map of the Al-Hillah city, Babylon province.

3.2. Methodology

The proposed methodology comprises the implementation of two models; fuzzy logic and Artificial Neural Network (ANN) to detrermine suitable locations for establishing recreational sites (game city). Figure 2 shows the flowchart of the proposed allocation methodology. The first step is data preparing. The used dataset in this study have been collected from Babylon Municipalities Directory. The input data were collected as a GIS data (shapefile format). The input parameters represent built up areas, roads, green areas, railway, water bodies, and population density. The second step is spatial analysis based on, Euclidean distance tools to measure the real distances from any features. A reclassification technique was used to classify these distances to get unique values to facilitate the analysis process. The third step is applying the first model based on Fuzzy logic to produce suitability map and second to apply ANN algorithm based on parameters mentioned above, population density, and the samples of suitable locations resulted from Fuzzy logic by using MATLAB software. The result of ANN was converted to GIS software using conversion tools (convert table to points and convert points to raster), then the final raster was produced based on ANN algorithm.

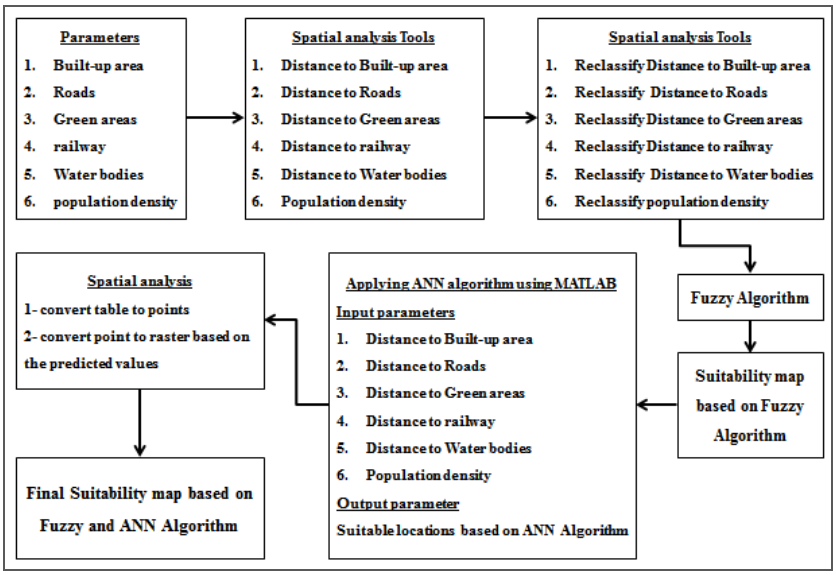

Figure 2. The proposed methodology

The model criteria were determined depending on the requirement of the local government in Babylon province, Iraq. On the other hand, GIS data were prepared depending on available data with the government.

3.3. The data collection

The data for this study were collected from three different resources:

1- Babylon Municipalities Directory.

2-Babylon Statistics Directory.

3- Some data have been purchased from some Web-sites.

The collected data consists of several layers that contain geospatial data and metadata. These layers are: Railway, River, Road network, Green Area, used land and population, as shown in Figure. 1. We used some criteria for recreational allocation based on spatial dataset (Table 1).

Table 1. the used criteria for recreational allocation.

No.	Parameter	Criterion
1	Builtup areas	Near to builtup areas
2	Roads	Near to roads
3	green areas	Near to green areas
4	Railway	far from Railway
5	Water bodies	Far from water bodies
6	population density	near to high population density

3.4. The Suitability analysis

Site selection or suitability analysis is a type of analysis used in GIS to determine the best place or site for some applications. Potential sites used in suitability analysis can include the location of a new hospital, school, or game city among many others [14]. When performing allocation analysis, users must set various criteria from which the GIS software can rate the best or ideal sites. Allocation analysis can be performed with vector or raster data. One of the most widely used types of analysis is "weighted allocation" which uses raster data [14]. In this study, we applied two algorithms (ANN and Fuzzy logic) and and GIS modeling based on several parameters; built-up areas, roads, green areas, railway, water bodies, and population density to find suitable locations to establish a recreational site in Al-Hilla city, Iraq.

3.4.1. Spatial analysis techniques

In this study we prepared a spatial layer based on spatial analysis tools. The Euclidean distance was used [15] to calculate distances to each criterion (Distance to Built-up area, Distance to Roads, Distance to Green areas, Distance to railway, Distance to Water bodies, and population density). The Euclidean distance tools describe each cell's relationship to a source or a set of sources based on the straight-line distance. There are three Euclidean tools: Euclidean Distance gives the distance from each cell in the raster to the closest source, (Figure 3). With the reclassification technique, we can modify values within raster to specific values (i.e. ranks). Each rank represents a group of data or class. The reclassification result is obtained by a new raster layer. The main reason to do the reclassification process is to facilitate spatial analysis by grouping entries, reclassifying data to a specific scale, and assigning values to NoData cells. In order to implement this task, we have used a spatial analysis tool so-called (Reclassify tools) [16] to classify distances to each criterion to 10 ranks (Figure 4).

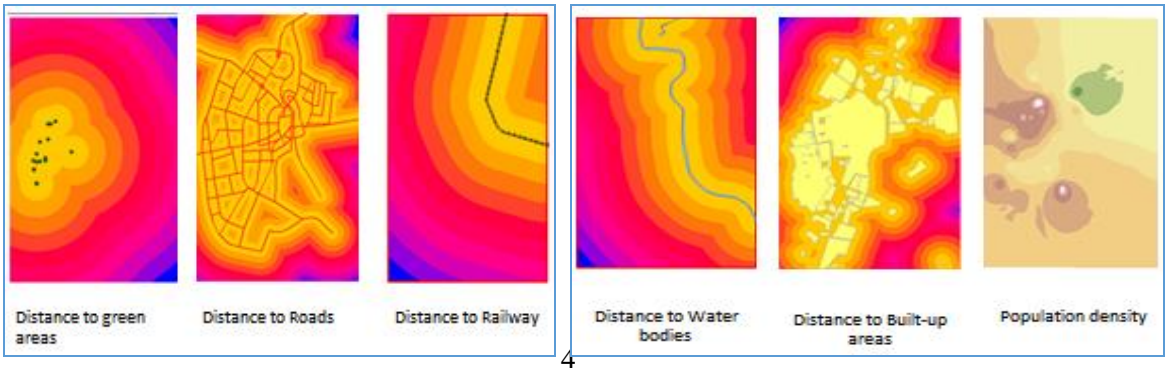

Figure 3. Euclidean distance to the considered criteria and population density.

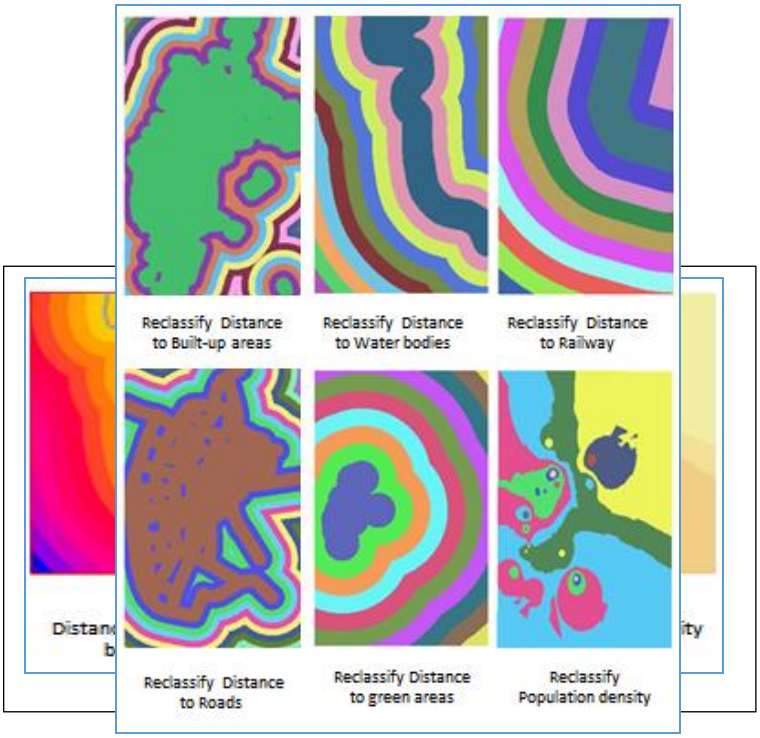

Figure 4: Reclassify Euclidean distance to the considered criteria and population density

3.4.2. Data Analysis by Fuzzy Overly Algorithm

The fuzzy logic methods have been developed to model ambiguity in both attribute and geometry of geospatial data [17]. In terms of overlay analysis, fuzzy logic methods usually focus on ambiguity or inaccuracies in the semantic data (attributes). Generally, ambiguity occurs in two areas within attribute data (features definition, phenomena's measurement). These inaccuracies lead to errors during assigning cells to a specific class. Consequently, ambiguity can negatively impact decision-making operations. Thus, fuzzy overlay tools can help decision-making operations by modeling ambiguity in class boundaries [18]. Theoretically, fuzzy logic system is trying to work as close as human perception, which assumes that people not only thinking about definite variables (yes or no) but also thinking about "blurry" values like (maybe yes, maybe no). Therefore, fuzzy logic system capable of working with blurred boundaries and cloudy information [19]. Fuzzy logic overlay process is definitely working by setting a membership value to the resulted locations ranged between 0 and 1. Which 0 value refers to unsuitable or non-membership. While 1 value indicates a suitable site or membership [18]. In this study, we have used 6 parameters as input parameters (Reclassify Distance to Built-up areas, Reclassify Distance to Water bodies, Reclassify Distance to Railway, Reclassify Distance to Roads, Reclassify Distance to green areas, Reclassify Population density). Then we applied the raster overlaying based on Fuzzy logic (Figure 5).

3.4.3. Artificial Neural Network

Artificial Neural Networks (ANNs) is one of the popular machine learning algorithms, which are designed on the basis of biological neurons architecture to model the relationship between input-output data [20].

Similar to biological neurons, (ANNs) receive several inputs, then process them as matrix calculations, then produce a single value with an activation function. As shown in equation (1):

$$y=f(w^t x)+b \quad (1)$$

Where, y refers to the output, f (:) refers to the activation function, w is the weight vector, in addition x is the input vector. On the other hand, b refers to the bias parameter that adds non-linearity function to the model before the activation. In general, Neural networks consisting of input layers, hidden layers, output layers. In this study we implemented ANN model by using MATLAB software, and used 6 parameters as input parameters (Distance to Built-up area, Distance to Roads, Distance to Green areas, Distance to railway, Distance to Water bodies, population density), and the suitable locations obtained from Fuzzy logic algorithm were used as output parameters. Then we converted the ANN table to points depending on coordinates and using spatial analysis tools, then these points were converted to raster layers based on predicted values.

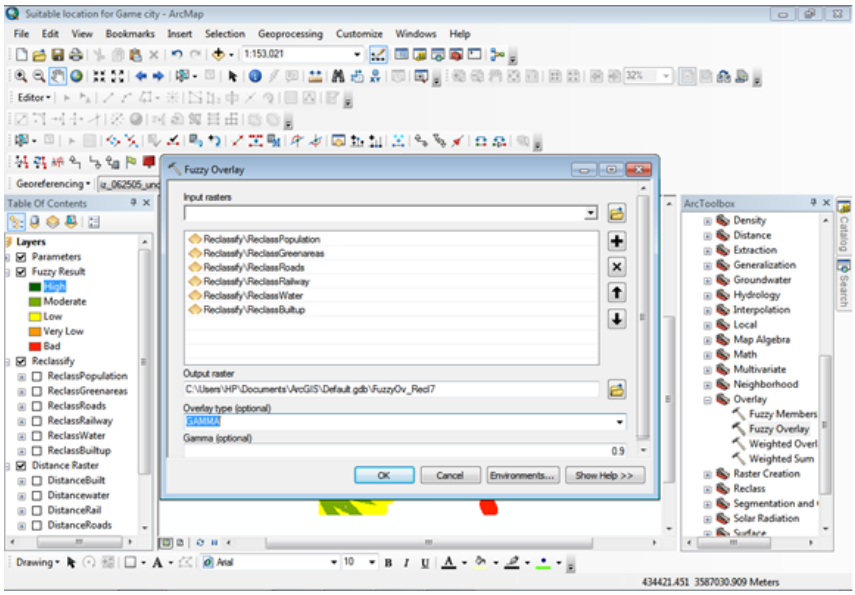

Figure 5: Fuzzy Algorithm implementation.

4. Results and Discussion

4.1. Results of fuzzy logic algorithm

Fuzzy modeling has included fuzzy overlay process for 6 parameters (i.e. reclassified distances to Built-up areas, reclassified distance to Water bodies, reclassified distance to Railway, reclassified distance to roads, reclassified distance to green areas, reclassified population density layer). Then the Fuzzy model transforms the input raster into a 0 to 1 scale, indicating the strength of membership in a set, based on a specified fuzzification algorithm. In this study, we used gamma membership function (ArcGIS help). Due to the capability of Gamma membership function to establish a relationship between multiple criteria compared to other membership functions like (AND – OR) functions that only return the value of a single fuzzy membership set [21]. It has produced a suitability map with distortions that approximately less than other membership functions.

A value of 1 indicates full membership in the fuzzy set, with membership decreasing to 0, indicating it is not a member of the fuzzy set. The final step is the Fuzzy Overlay tool in ArcGIS allows the analysis of the possibility of a phenomenon belonging to multiple sets in a multicriteria overlay analysis. The Fuzzy Overlay not only determines what sets the phenomenon is possibly a member of, but it also analyzes the relationships between the membership of the multiple sets. The fuzzy model combined with spatial modeling to produce suitability map. The impact weight of each layer was; population density = 0.11, distance to built-up areas =

0.3428, distance to roads = 0.1035, distance to green areas = 0.2565, distance to railway = 0.0163, distance to water bodies = 0.1709. According to the final results of Fuzzy logic, the study area was classified into five classes, each class has a specific ranked categorized (high, moderate, low, very low, and bad). Figure 6 shows the result of Fuzzy logic as a suitability map. The high suitable locations were illustrated by dark green color and the moderate ones with light green. The resulted map considered as a primary map for decision-makers to make further investigations to find suitable locations. According to the fuzzy modeling, the high suitable class for constructing game city covers 15 green area locations and neglected 2 locations. This result can be validated using field works and also can find the exact location by adding extra parameters such as specific area, location shape, and so on.

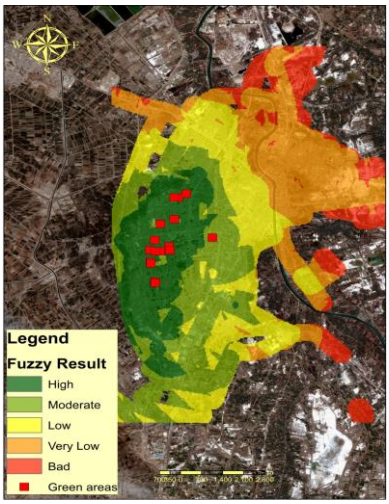

Figure 6. The suitable location based on Fuzzy Algorithm.

4.2. Results of ANN algorithm

In this study, back-propagation neural network based on 6 parameters as input parameters (Distance to Built-up area, Distance to Roads, Distance to Green areas, Distance to the railway, Distance to Water bodies, population density), and Fuzzy suitability results as an output parameter was implemented based on 6 layers and 3 neurons for each layer in MATLAB software. The ANN was trained and validated depending on (921849 and 395078) samples respectively. These samples were derived from image pixels by converting pixels to points. Then attributes within all parameters mentioned above were connected to points (samples). These attributes were then transformed into tabular data to easily be used in the ANN model. The model accuracy reached 74%. According to the final results of ANN algorithm, the study area was classified into five classes, each class has a specific rank (high, moderate, low, very low, bad). Figure 7 shows the result of ANN algorithms. The high suitable locations were illustrated in the map by green color, which is very relevant to the criteria. The moderate was illustrated by orange color. The high suitability area covers all green areas in the study area (17 locations) without neglecting any existing area.

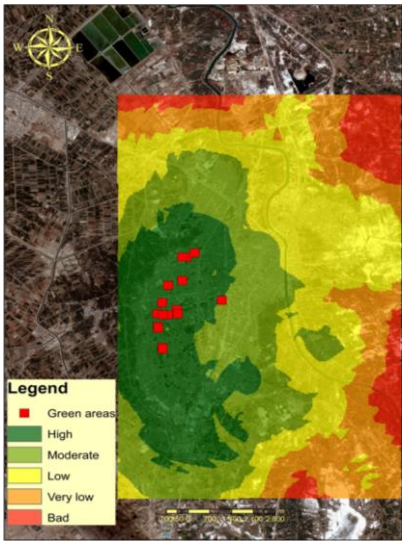

Figure 7. The suitable location based on ANN algorithm.

4.3. Comparison between Fuzzy and ANN algorithms results

According to the produced suitability maps for recreational services, the fuzzy model obtained a higher suitable areas with an approximate area of 15.1 square kilometers. Higher suitable areas covered 15 locations of 17 green area sites. In comparison with the result obtained by the ANN model, the higher suitable areas achieved approximately 29.2 square kilometers and it's covering all green area locations. From these results we can conclude that the fuzzy model obtained less area than ANN model. It is noteworthy, higher suitable areas resulted from the fuzzy model have excluded two sites of green areas compared to the ANN model. Where these green area locations have been chosen by the government for future development. Thus, the model that covered less green area locations will reduce the uncertainty among governmental agencies. Consequently, it will reduce the time and cost of further field-investigations. The Iraq government proposed a future plan for the development of recreational sites. Seventeen locations have been nominated by decision-makers to be a new recreational site in the study area. Our results were represented by maps using integrated GIS tools and Fuzzy logic and ANN algorithms. The suitable map generated based on the Fuzzy logic was showed more feasibility than the map generated based on the ANN algorithm. Fuzzy logic excluded 2 sites from the total green area sites, which has reduced the uncertainty among decision-makers. As a result, the suitability map based on Fuzzy logic algorithm will be useful for decision-makers by reducing field investigations, cost, and time. Therefore, the Fuzzy logic showed more effective performance than ANN algorithm. Table 2 shows the comparison between Fuzzy and ANN models in term of the covered areas and the number of covered green areas.

Table 2. Comparison between Fuzzy and ANN results for recreational allocation.

Allocation Model	Area of high suitable class (Km^2)	Number of covered green area locations
Fuzzy	15.1	15
ANN	29.2	17

Final results showed that the fuzzy model outperformed the ANN model, where the fuzzy model reduced the uncertainty among decision-makers by covering less green area locations than the ANN model.On the other hand, the processing time of implementation of Fuzzy logic was less than the processing time of using the ANN algorithm, due to the training process of the ANN algorithm, which is considered a time-consuming step. The implementation time of the Fuzzy model was 5 minutes while ANN algorithm required 30 minutes. Therefore, we urge users who dealing with suitability analysis with the lack of criteria weights to use the fuzzy models.

5. Conclusion

Recreational services play a vital role in urban development in the world. There are several methods to find suitable locations for recreational sites. Spatial techniques have recently attracted experts due to their applicability and capability to find locations through GIS environments, which reduce the time and cost of field works. Therefore, in this paper we proposed two algorithms (Fuzzy logic and ANN) to create suitability maps for establishing recreational site in Hilla city, Iraq. Final results showed that the fuzzy model outperformed the ANN model, where the fuzzy model reduced the uncertainty among decision-makers by covering less green area locations than the ANN model. Furthermore, Fuzzy logic algorithm outperformed ANN algorithm in terms of processing time. In conclusion, the fuzzy logic model can be used as an effective tool in the suitability analysis that lacks criteria weights.

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