



Identifying the most suitable locations for nuclear power in Abu-Ghraib district using GIS and remote sensing

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Following the industrial revolution that the world witnessed in recent centuries, the need arose for energy sources to supply factory machinery and means of transportation with the power that enables them to perform their work, the need to find diverse energy sources through which countries can generate electricity. This research aims to identify suitable locations for establishing nuclear power plants in the Abu-Ghraib district using Geographic Information Systems (GIS) techniques and satellite imagery to study and analyze land use and the area's topography, including slope, elevation, and water sources, using the Analytical Hierarchy Process (AHP) method. Assigning relative weights to each criterion according to its importance in the suitability of the nuclear site and producing the final suitability map. All criteria are integrated into a final suitability map highlighting the most suitable sites for nuclear energy using a hierarchical analysis method and integrating the relative weights of each criterion according to its relative importance in determining the location of nuclear energy. The results showed that there are large areas in the Abu-Ghraib district suitable for the construction of nuclear power plants, due to the availability of water sources for cooling the plants, low population density. That the very high suitability category (26.07%) and the high suitability (30.91%) and their sum (56.98%). The potential application of nanotechnology in supporting the safety and performance of nuclear facilities for protection against nuclear radiation.

Keywords: Analytic Hierarchy Process (AHP); GIS; Spatial analysis; Water sources.

1. INTRODUCTION

One of the modern technologies that has contributed to the development of nuclear energy is nanotechnology, through increasing the ability of nuclear reactors to withstand high temperatures and radiation. Supporting the safety and efficiency requirements of nuclear facilities by leveraging the properties of nanomaterials in nuclear energy-related applications [1]. Studying the selection of suitable sites for the construction of nuclear power plants is a delicate process because it depends on a large number of natural, environmental, and human factors such as topography, slope, elevation, land use, residential areas, agricultural areas, water sources, and others. Following the industrial revolution that the world witnessed in recent centuries, the need arose for energy sources to supply factory machinery and means of transportation with the power that enables them to perform their work, the need to find diverse energy sources through which countries can generate electricity [2]. Nuclear energy is energy produced through atomic nuclear reactions and is used to generate electricity by evaporating water to produce electrical power. Nuclear energy relies on uranium, which is extracted from the earth through mining. The atoms of this element split through nuclear fission. Nuclear power plants occupy relatively small areas of land compared to solar or wind power plants, but the use of nuclear energy causes the production of highly radioactive waste. Spent nuclear fuel is stored in water tanks for cooling, absorption of harmful radiation, and reduction of its radioactivity. It can then be recycled and reprocessed to recover un-fessed uranium for reuse as fuel for nuclear reactors or nuclear weapons [3]. Geographic Information Systems (GIS) can be used not only to study and analyze information available in a geographic information database, but also to study and analyze information resulting from planning, urban and environmental models, and to reproduce geographic and graphical information [4]. Geographic analysis is time-sensitive, as planning, urban, and environmental studies require understanding how these plans change or are affected over multiple periods. Using Geographic Information Systems (GIS), we can identify these changes over time and illustrate urban expansion [5].

One of the benefits of remote sensing technology is detecting changes in land cover. Land cover means the land features found in a particular geographical area of the Earth's surface. These land features include: residential areas, agricultural fields, rivers, lakes, seas, mountains, forests, plateaus, valleys, glacial areas, and others [6]. Remote sensing technology plays a major role in detecting and calculating the extent of change in land cover of all types in a specific area of the Earth's surface, whether changes arising from human activity or from the impact of natural forces, through repeated satellite imaging of this geographical area at different and widely spaced time intervals [7]. Data taken from remote sensing satellites is used to provide detailed information about the Earth's surface [8]. The aim of this research is to identify the most suitable locations for nuclear power plants using remote sensing techniques and geographic information systems by integrating criteria of relative importance to the nuclear site with the analysis hierarchy process.

The Abu Ghraib district is administratively located in the western part of Baghdad Governorate. Astronomically, between two lines of longitude ($43^{\circ} 49' 30''$) east and two lines of latitude ($33^{\circ} 22' 30''$) north. It is bordered to the north by the Kadhimiya district, to the south by the Mahmudiya district, to the east by the Karkh district, and to the west by the Fallujah district [9].

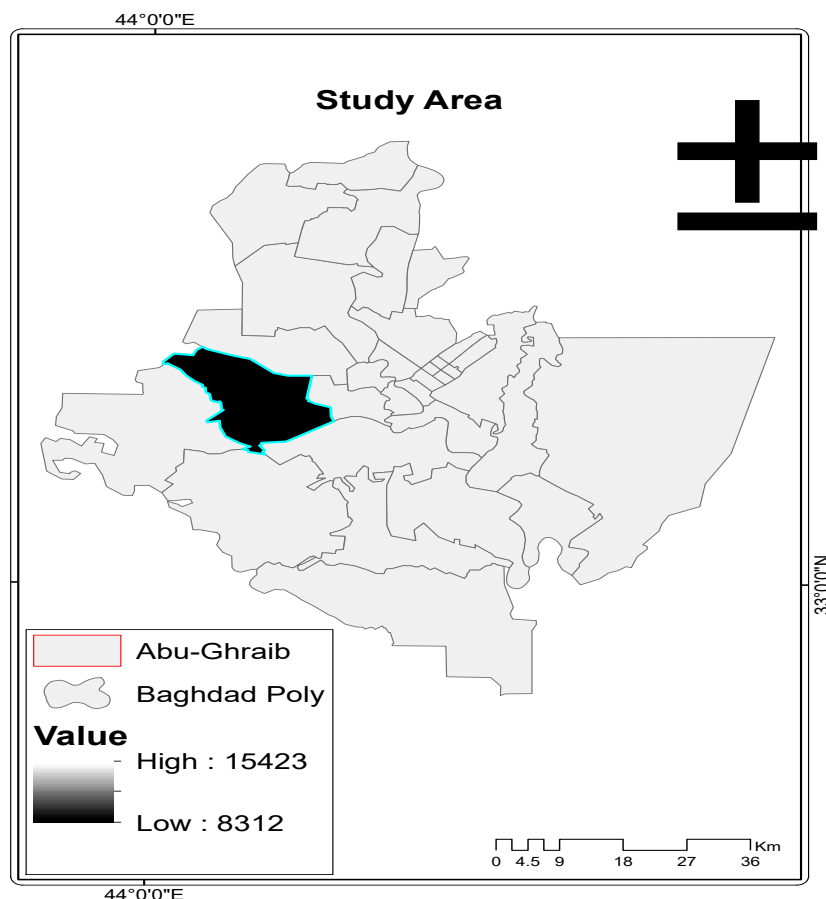


Figure 1 Location of Abu-Ghraib District in Baghdad Governorate.

2. METHODOLOGY

3.1. Data collection and processing

This research relied on a set of spatial data to identify suitable locations for a nuclear power facility. These include Landsat images 8 for extracting land use and land cover data, and a digital elevation model (DEM) for extracting slope and elevation data and water source layer [10]. Land cover classification: Mapping and classifying land cover involves identifying the physical condition of the Earth's surface and then dividing the land area into different categories such as soil, forest, grassland, snow, water bodies, etc., according to their physical state [11]. Land cover classification helps in locating the natural resources present on the Earth's surface [12]. The data processed using ArcGIS software version 10.4, where the processing included cropping the data on the study area, reviewing the data, removing errors, and standardizing the coordinate system into formats suitable for spatial analysis [13].

3.2. Land use and land cover (LULC)

The concept of land cover describes the natural resources of the Earth's surface, such as plants, rocks, rivers, lakes, and so on. Land use, on the other hand, describes the use of a particular piece of land, whether agricultural, industrial, or urban. Land cover refers to the shape of the Earth's surface, while

land use represents the function of that shape [14]. Therefore, monitoring land cover change and land use has included unsupervised classification processes [15]. This method relies on grouping pixels with similar spectral characteristics without prior training data to classify satellite imagery and identify land cover categories within the study area [16].

3.3. Analytic hierarchy process (AHP)

Four main criteria are used to determine the suitability of sites for nuclear energy: land use, land cover, slope, digital elevation, and far from water areas. The hierarchical analysis method is adopted because it is considered one of the most widely used methods in geographic information systems studies [17]. The hierarchical analysis method is adopted because it is considered one of the most widely used methods in geographic information systems studies. These weights are then combined with spatial criteria layers within the GIS environment to produce the final fit map. The method relies on building a pairwise comparison matrix between the studied criteria, where each criterion is evaluated in comparison with the other criteria [18].

3.4. Nanotechnology applications in nuclear facility safety

Nanomaterial applications are an important factor supporting safety requirements in nuclear facilities. Due to the possibility of improving its physical properties and its ability to provide effective radiation protection. Nanotechnology applications play a supporting role alongside remote sensing and geographic information systems to enhance nuclear radiation safety requirements in areas suitable for nuclear energy [19].

4. RESULTS AND DISCUSSION

Constructing a color image is essential because it enhances visual interpretation. A color image is designed consisting of a set of spectral bands. Its primary purpose is to isolate the components of the Earth's surface from one another based on the wavelength of light reflected from each feature on the Earth's surface. Land uses are divided into five main categories: vegetation, urban areas, sparse vegetation, water, and Bare soil. As shown in Figure (2), where Figure (A) represents the process of combining spectral beams, Figure (B) represents the unsupervised classification of land use and land cover, and Figure (C) represents the reclassification of LULC according to suitability for a nuclear power site.

Table1 Classification of LULC categories for Abu-Ghraib district according to suitability.

LULC Categories	Area km ²	Area%
Very High	56.96	23.55
High	60.64	25.07
Medium	37.79	15.62
Low	63.67	26.32
Very Low	22.87	9.45

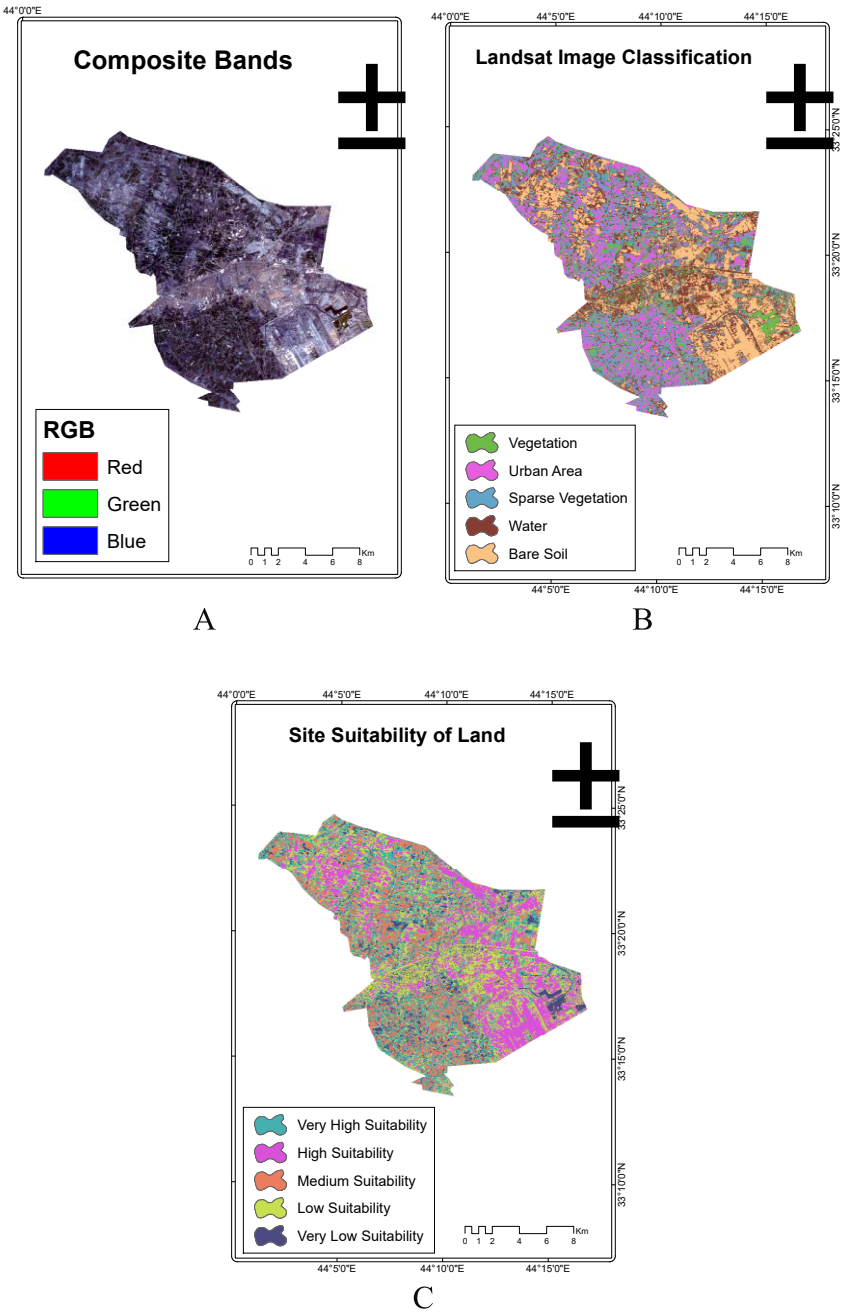


Figure 2 Unsupervised classification of LULC and their classification according to suitability in Abu-Ghraib district.

Table (1) and Figure (2) show that the results of the analysis of LULC data suitable for establishing nuclear power sites fall within barren lands, sparsely populated areas, and agricultural lands devoid of vegetation. The further a nuclear power site is from populated areas, areas with water bodies, and agricultural areas, the more suitable the site is in terms of construction due to its distance from human use and the agricultural environment.

From the figure (C), we observe that the suitability levels are divided into five categories: very high suitability and high suitability, represented by desert areas and areas far from population centers, respectively. As for agricultural areas and water areas, the suitability level is medium to very low, in order to protect agricultural areas and water from contamination by the nuclear site.

4.1. Spatial analysis of slope

Nuclear power sites require level and stable land, and slope is an important factor as the degree of slope affects the stability of the nuclear site to ensure the stability of nuclear reactors. Figure (A) illustrates the spatial analysis of the slope for the Abu-Ghraib area, while Figure (B) illustrates the reclassification of the slope according to its suitability for establishing a nuclear site.

Table 2 Spatial analysis of slope categories for Abu-Ghraib district.

Slope Categories	Area km ²	Area%
Very High	1.88	0.78
High	19.98	8.26
Medium	51.01	21.08
Low	93.23	38.54
Very Low	75.82	31.34

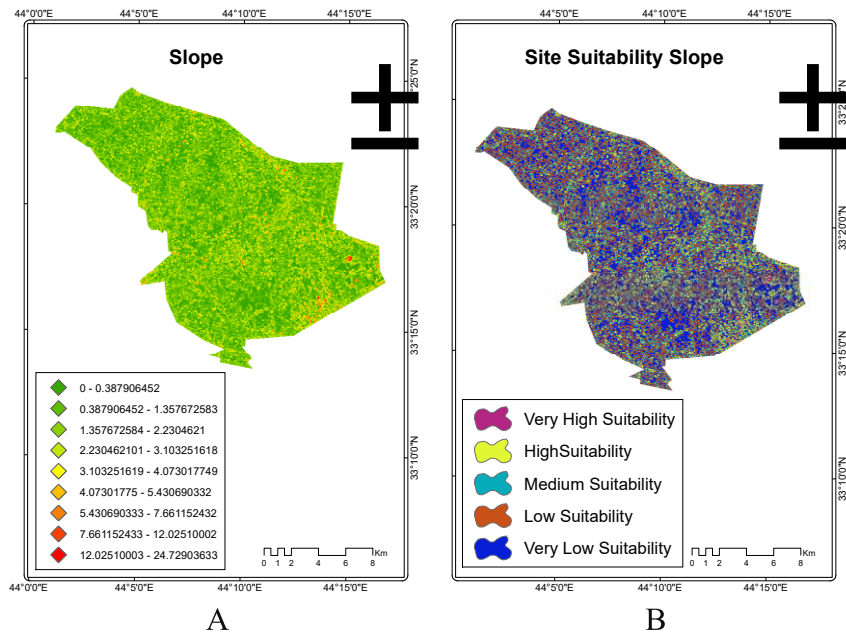


Figure 3 Spatial analysis of slope categories for Abu-Ghraib district according to suitability.

Figure (A) show the Spatial analysis of slope categories for Abu-Ghraib district and figure (B) show that the slope is divided into five suitability categories. Very high suitability and high suitability represent the most suitable categories for establishing a nuclear site. The lower the slope, the more suitable it is for nuclear energy, reducing excavation and leveling operations for the nuclear site. The medium suitability, low suitability, and very low suitability categories are characterized by high slopes, meaning the ground surface is elevated and unsuitable for a nuclear power site.

4.2. Spatial analysis of digital elevation

The establishment of nuclear power plants requires suitable topographical conditions for the safe construction and operation of nuclear power stations, and altitude is a significant factor as it is related to the nature of the terrain and the stability of the site. As shown in Table (3) and Figure (4), the height is divided into five suitability categories. The very high and high suitability categories are the most suitable for the nuclear site as they had lower heights, while the medium to low and very low suitability categories are the least suitable as they had higher heights.

Table 3 Spatial analysis of elevation categories for Abu-Ghraib district.

Elevation Categories	Area km ²	Area%
Very High	72.88	30.13
High	105.24	43.5
Medium	45.74	18.91
Low	17.02	7.03
Very Low	1.04	0.43

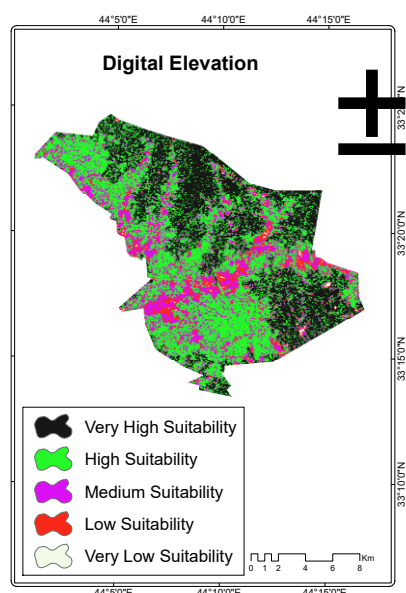


Figure 4 Spatial analysis of elevation categories for Abu-Ghraib district according to suitability.

4.3. Water sources

Distance from water sources is an important criterion in choosing nuclear power sites to protect the aquatic environment from nuclear pollution and any effects arising from nuclear sites. Nuclear power plants require large water sources such as rivers, lakes, and seas to cool the nuclear sites; the closer they are to a water source, the better the location for nuclear power. As shown in Table (4) and Figure (5), where Figure (A) represents the distance from water sources and Figure (C) represents the reclassification of water sources according to suitability levels.

Table 4 Spatial analysis of water sources categories for Abu-Ghraib district.

Water Source Categories	Area km ²	Area%
Very High	32.71	35.94
High	25.13	27.61
Medium	17.41	19.13
Low	12.38	13.6
Very Low	3.39	3.73

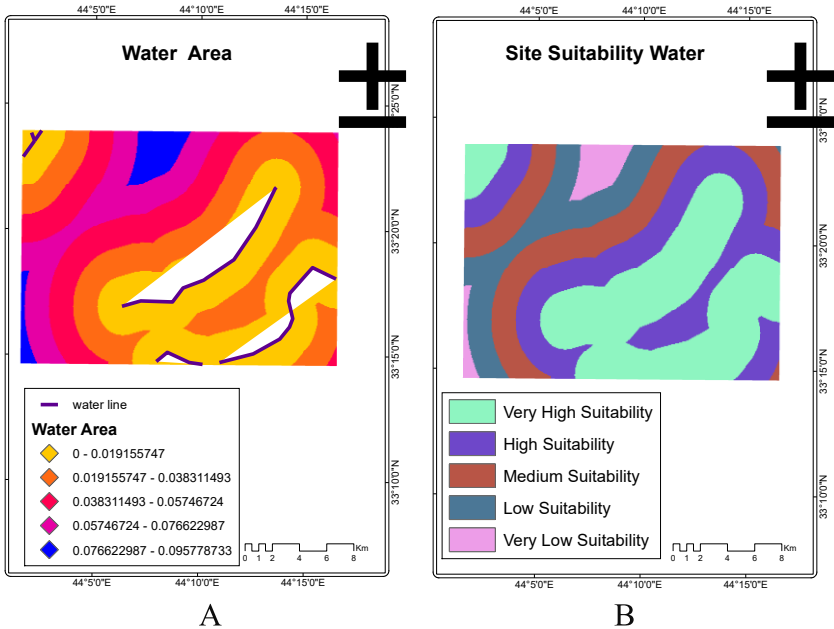


Figure 5 Spatial analysis of water sources categories for Abu-Ghraib district according to suitability.

In Figure (A), we observe that the visible blue line above, below, and in the middle of Abu-Ghraib district represents water sources. In Figure (B), we observe that the green color represents water sources, which are divided into five categories based on suitability. Very high and high suitability are the most suitable for establishing a nuclear site because they are near from water sources. Medium, low, and very low suitability categories are considered unsuitable for a nuclear site due to their far to water.

4.4. Analytic hierarchy process (AHP)

The analysis hierarchy method is used to determine the relative importance of each criterion in selecting suitable sites for nuclear energy in Abu-Ghraib district, based on the relative importance of each criterion. Land use (25%), soil (15%), digital elevation (10%), distance from water sources (50%). All spatial criteria are combined after assigning them relative weights. As show in table (5) and figure (6).

Table 5 Analytic hierarchy process after combining all criteria according to their relative importance.

AHP Categories	Area km ²	Area%
Very High	14.13	26.07
High	16.75	30.91
Medium	11.8	21.78
Low	7.73	14.26
Very Low	3.78	6.98

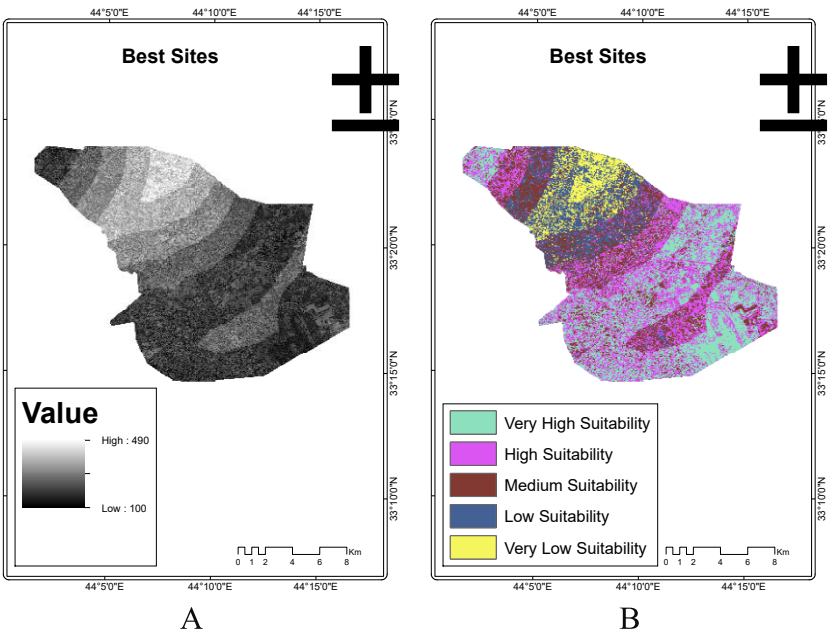


Figure 6 Final map of the best sites for nuclear power plants in Abu Ghraib district.

In figure (A) illustrates the integration of all criteria according to their relative importance into a single map. In figure (B) divided into five categories based on suitability for a nuclear site: very high suitability and high suitability are the most suitable for a nuclear site, while medium to low and very low suitability are unsuitable for establishing a nuclear site.

Based on the above results, the selection of highly suitable areas according to the spatial analysis results can be integrated with the application of nanotechnology to support safety and protection levels from nuclear radiation. This integration between spatial analysis and nanotechnology is a supportive technological trend that can enhance the efficiency of future planning for nuclear facilities.

5. CONCLUSIONS

Baghdad Governorate, including Abu-Ghraib District, enjoys good locations for operating its nuclear power plant in preparation for meeting its energy needs, including electricity demand. This study identified the most suitable sites for nuclear energy based on four important criteria: land use and land cover, slope, elevation, and water sources. These criteria were represented in GIS layers, and then the criteria were ranked based on the most important criterion for determining the nuclear location. All criteria were integrated into a final suitability map highlighting the most suitable sites for nuclear energy using a hierarchical analysis method and integrating the relative weights of each criterion according to its relative importance in determining the location of nuclear energy. Table (5) show that the very high suitability category (26.07%) and the high suitability (30.91%) and their sum (56.98%) The percentage of Abu-Ghraib spent on establishing nuclear power plants is considered good. Figure (6B), we observe that the green and violet colors appearing in the final suitability map represent the most suitable areas for establishing nuclear power plants. This is due to them far from residential areas, near water sources, and far agricultural areas, thus protecting the residential, water, and agricultural environment from nuclear pollutants that harm the human environment in general. From the results above, we observe remote sensing techniques and geographic information systems have proven their effectiveness in analyzing spatial factors to select suitable sites for nuclear energy. Land use data showed that unused or low-human activity land is more suitable than residential and agricultural areas. Areas with low slopes and low and moderate elevations were more suitable due to the ease of establishing and operating nuclear power plants. As for the criterion water sources, the near the sites were from water, the more suitable they were for a nuclear site. This study contributed to reducing the time, effort, and cost of field surveys for any area before undertaking a project by looking at the final suitability map and identifying the most suitable areas for the region. This method can be applied to any area in the governorate of Iraq. The potential for expanding the scope of geographic information systems and remote sensing applications in future studies by integrating nanotechnology into the development phases of nuclear facilities is enhanced by this trend, which fosters integration between spatial analysis techniques and recent advancements in nanotechnology.

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