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Verifying the Best Iraqi Area to Install a LOFAR Radio Telescope Using SWOT Model

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Abstract

Many of the radio telescope's wireless sensor networks operate outdoors, where changing weather might impact their system performance. Therefore, it is necessary to explore the climatic and topographic factors that affect the quality of the radio link to mitigate its impact and adapt to different conditions. In this study, the effects of the region's topography and climate on the strength of the radio signal were studied. Besides studying the effects of the soil of the area and land flatness on determining the optimal location for erecting a radio telescope in Iraq within four governorates (Nineveh, AL-Anbar, Al-Najaf, and Al-Muthanna). Data from relevant ministries and a digital map dataset for the area's topography with dimensions of 4 km x 6 km were used. The obtained results, via applying the SWOT model, showed that the best Iraqi area for erecting a radio telescope (LOFAR) among the selected regions according to the atmospheric parameters, such as air temperature, relative humidity, and wind speed, and other conditions such as transportation, the security component, number of buildings, population, and communication towers was Al-Muthanna governorate. It is considered the best radio zone for observing radio signals.

Keywords: LOFAR Radio Telescope, Topography, Atmospheric parameter, SWOT Model.

التحقق من أفضل مكان في العراق لنصب التلسكوب الراديوي (LOFAR) باستخدام نموذج SWOT

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الخلاصة

تعمل العديد من شبكات الاستشعار اللاسلكية للتلسكوب الراديوي في الهواء الطلق، حيث يؤثر تغير الطقس على أداء نظامهم. لذلك، من الضروري استكشاف العوامل المناخية والطبوغرافية التي تؤثر على جودة الإشارة الراديوي للتخفيف من تأثيره والتكيف مع الظروف المختلفة. تمت في هذه الدراسة دراسة تأثيرات تضاريس المنطقة ومناخها على قوة الإشارة الراديوية. إلى جانب دراسة طبوغرافية المنطقة وتسطح الأرض في تحديد الموقع الأمثل لنصب تلسكوب راديوي LOFAR في العراق ضمن أربع محافظات (نينوى، الأنبار، النجف، المتى). استخدام بيانات الوزارات ذات الصلة ومجموعة بيانات الخرائط الرقمية لتضاريس المنطقة

بأبعاد 4 كم × 6 كم. أظهرت النتائج المتحصل عليها من خلال تطبيق نموذج SWOT . أن أفضل منطقة عراقية لإقامة تلسكوب راديوي بين المناطق المختارة حسب معايير الغلاف الجوي ، مثل درجة حرارة الهواء والرطوبة النسبية وسرعة الرياح ، وغيرها من الظروف مثل النقل ، والعامل الأمني وعدد الأبنية والسكان وأبراج الاتصالات هي محافظة المثنى. التي يعتبر أفضل منطقة رصد للإشارة الراديوية في العراق

Introduction

The Low Frequency Array (LOFAR) is a large distributed radio telescope, consisting of phased array antenna stations that are combined in an aperture synthesis array. The key science programs for LOFAR challenge the technical specifications in several directions, resulting in a highly reconfigurable architecture [1]. Many antennas used in constructing LOFAR and their outdoor applications are subject to changing their properties due to the environmental and atmospheric conditions at which these antennas are installed. Atmospheric conditions, in particular, can affect the performance of the antenna. The climate is one of the important factors affecting the various activities of the governorates (Nineveh, Al-Anbar, Al-Najaf, and Al-Muthanna) [2]. These governorates are distinguished by climate characteristics such as temperature, relative humidity, and wind speed that change and fluctuate temporarily with daily and seasonal variations, along with the spatial variations in the weather due to the local climate. Although these variations in weather conditions are inevitable and have significant impacts, they are usually measurable and can be mitigated based on experience. Thus, it is necessary to study the weather-related factors that affect radio link quality to minimize their impacts and adapt to different conditions [3-4]. Governorate user preference is strongly related to the complexity of the physical features of the urban structure, these physical features are presented as inputs perceived by users, these physical features will then be preserved in the user's memory as a result of the main occasions that took place in them[4]. The geographic information systems technology is considered one of the most important technologies that have multiple uses in the spatial dimension. This technology is a software application, used to create and display information, process, organize and analyze the spatial reference database and produce outputs in the form of a table and map [5-6]. Antennas that make up the radio telescope have been studied in many types of research; however, no consensus has been reached yet [7].

Some studies indicate that temperature is the dominant factor affecting radio signal quality [8-10]. Others claim humidity is the main factor, but some sources confirm other reasons, including wind speed, which controls the work of antennas and thus affects the efficiency of such radio telescopes [11]. Other studies used maps that represented topographical maps to show the Earth's features accurately that can be measured on a two-dimensional surface [12]. As the topographic maps are an excellent planning tool and guide with a detailed and accurate depiction of natural features on the Earth, such as roads, railways, power lines, lines, elevations, rivers, lakes, and geographical names [13]. To build a typical station, an area of land with a width of about 180 x 100 m², or a little more, is needed to ensure good sensitivity on longer baselines [14]. A topographic map is a two-dimensional representation of the three-dimensional landscape of the Earth by using the Digital Elevation Model (DEM), which is a numerical mapping data set representing a continuous topographic elevation surface across a series of cells. Each cell only contains information about the height of geological (ground) features, such as valleys, mountains, and landslides and does not include any elevation data related to non-terrestrial features, such as vegetation or buildings [15]. The DEM can create topographical maps of terrestrial terrain and bathymetric maps, which illustrate underwater landscapes [16].

Practical Framework

In the research phase, the specifications of the study area of four Iraqi governorates were studied to test and prove the possibility of installing a wireless telescope consisting of many antennas using the SWOT model, according to the climate and terrain of these areas. The study of the Earth's flatness in the selected areas was evaluated through the Digital Elevation Model (DEM), operating at low frequencies, to the extent of optimizing the best location for installing LOFAR radio telescopes. This showed us the values of the land heights accurately to get a comprehensive perception of the nature of the land in the selected areas. Alternatively, to identify the most suitable location for radio interference among the remote locations in Iraq, which are Nineveh, Al-Anbar, Al-Najaf, and Al-Muthanna, in terms of climate and terrain, the climate software ([http:// climate.onebuilding.org/](http://climate.onebuilding.org/)) was utilized to assess the temperature, humidity, and wind for each governorate. The images of the land elevation model used in this research had a spatial accuracy of 5 m horizontally and a vertical accuracy of 1 m. These models were taken, studied, and projected to a grid with dimensions of 4 X 6 km², to provide sufficient space to install radio stations.

After that, several essential specifications for installing stations were gathered and put into the SWOT model. This model considered the strengths, weaknesses, opportunities, and threats. It sorted the factors that affected the installation of stations based on the internal and external environment of the study area, where the strengths and weaknesses were. In contrast, the opportunities and threats were outside the study area and giving suggested and studied weights with the help of specialists in this field to obtain impartial and accurate results for choosing the best places for installing radio stations. Several locations were obtained in the study areas, some of which were suitable, and others needed to be more appropriate according to the DEM. Figures (1-4) show the chosen points to which the required specifications may apply in terms of altitude, as the global stations need, such as the relative specific height and an impact distance of 90 km [15].

The monthly average of atmospheric elements such as relative humidity, wind speed, and air temperature variables has great influence on the radio waves propagation through the troposphere (lower atmosphere). Thus, the received signal from any radio source will suffer from high degradation, especially those received by LOFAR telescope. The monthly average of atmospheric elements in the selected governorate, which are Nineveh, Al-Anbar, Al-Najaf, and Al-Muthanna according to the climate program, have been summarized in table 1.

Table 1: The monthly average air temperature, relative humidity and wind speed for Nineveh, Al-Anbar, Al-Najaf, and Al-Muthanna governorates.

Governorate	Temperature C°	Humidity (%)	Wind m/Sec
Nineveh	21.1	46.25	254.1
Al-Anbar	23	42.6	253.3
Al-Najaf	24.4	36.5	271.6
Al-Muthanna	24.1	36	293.3

On the other hand, the topography of each of the selected governorates was also tested and demonstrated in the maps shown in Figures (1-4). The topography of each governorate, Figures (1-4)A, shows the area's height and flatness measured in units of meters with a color scale ranging from green (minimum value) to red (maximum value). While, Figures (1-4)B

reveal the topography fish net model for the selected governments. The line presents the most suitable space for flat land to efficiently install a radio telescope

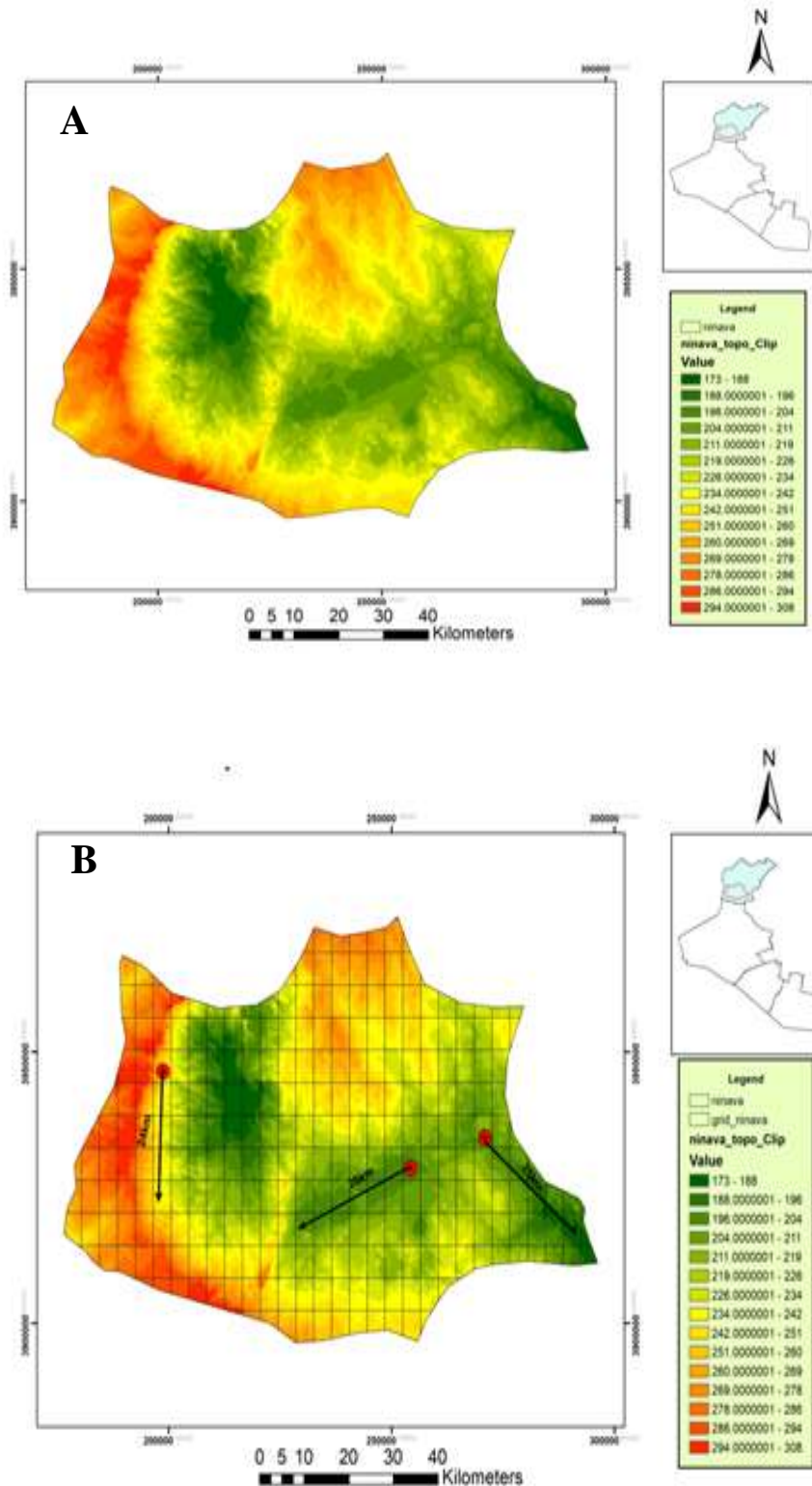


Figure 1: A) The topography of Nineveh governorate indicated the area’s height and flatness measured in meters, the color ranges from the minimum value (green) to the maximum (red) **(B):** Fish net model of topography in Nineveh governorate, the line presents the most suitable space for flat land to install a radio telescope.

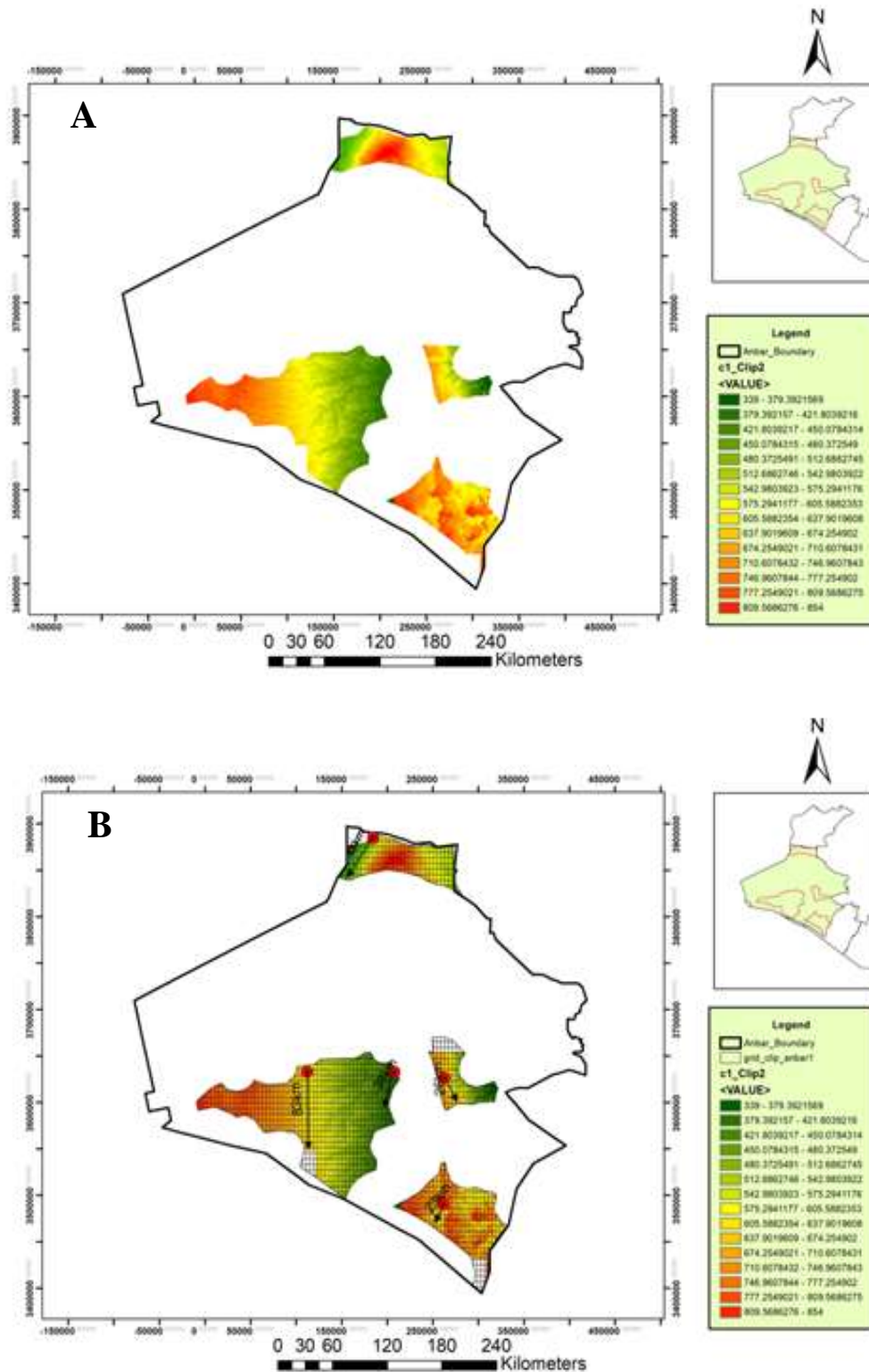


Figure 2: A) The topography of Al-Anbar governorate indicated the area’s height and flatness measured in meters, the color ranges from the minimum value (green) to the maximum (red).

(B): Fish net model of topography in Al-Anbar governorate, The line presents the most suitable space for flat land to install a radio telescope.

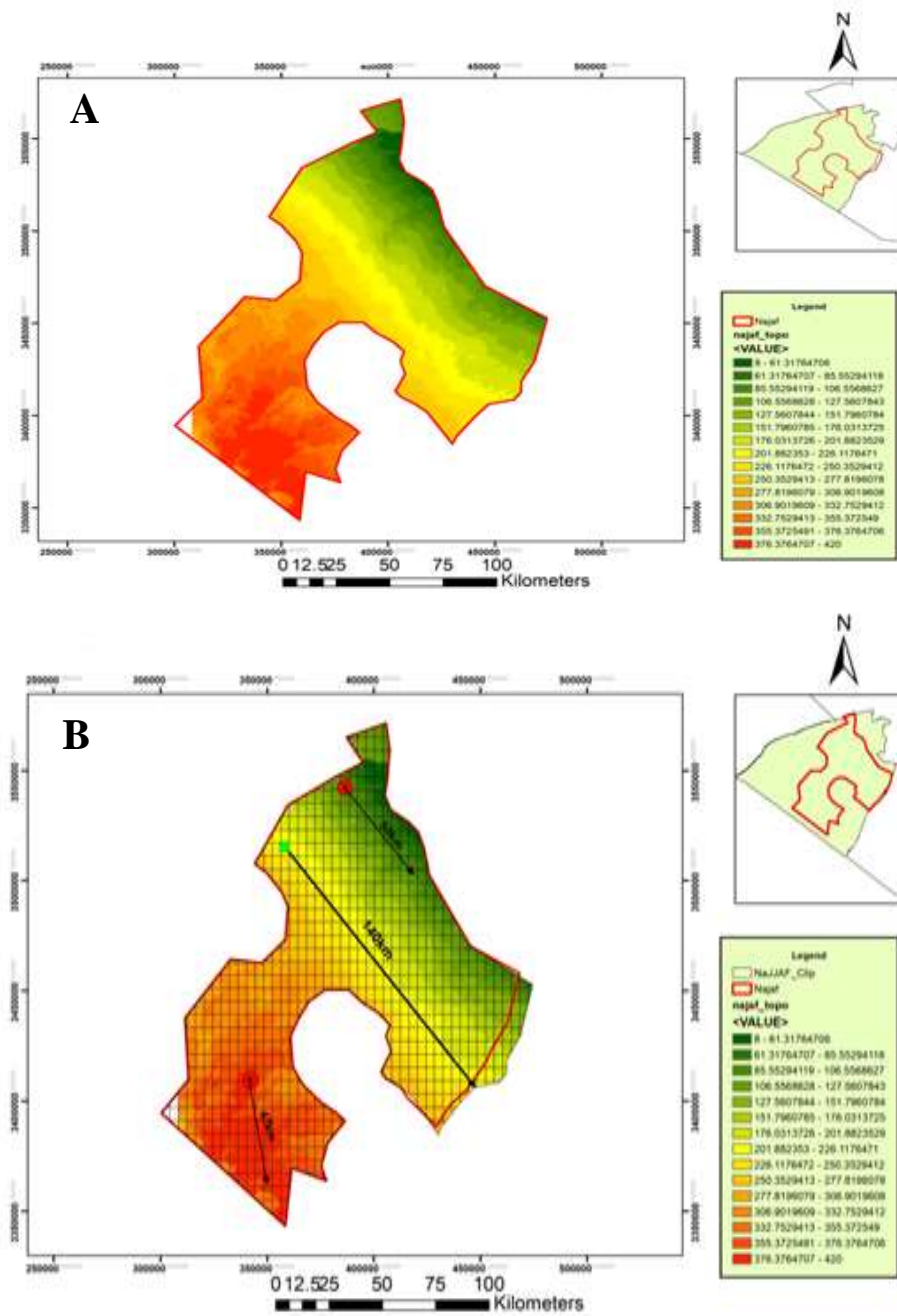


Figure 3: A) The topography of Al-Najaf governorate indicated the area’s height and flatness measured in meters, the color ranges from the minimum value (green) to the maximum (red).

(B): Fish net model of topography in Al-Najaf governorate, the line presents the most suitable space for flat land to install a radio telescope.

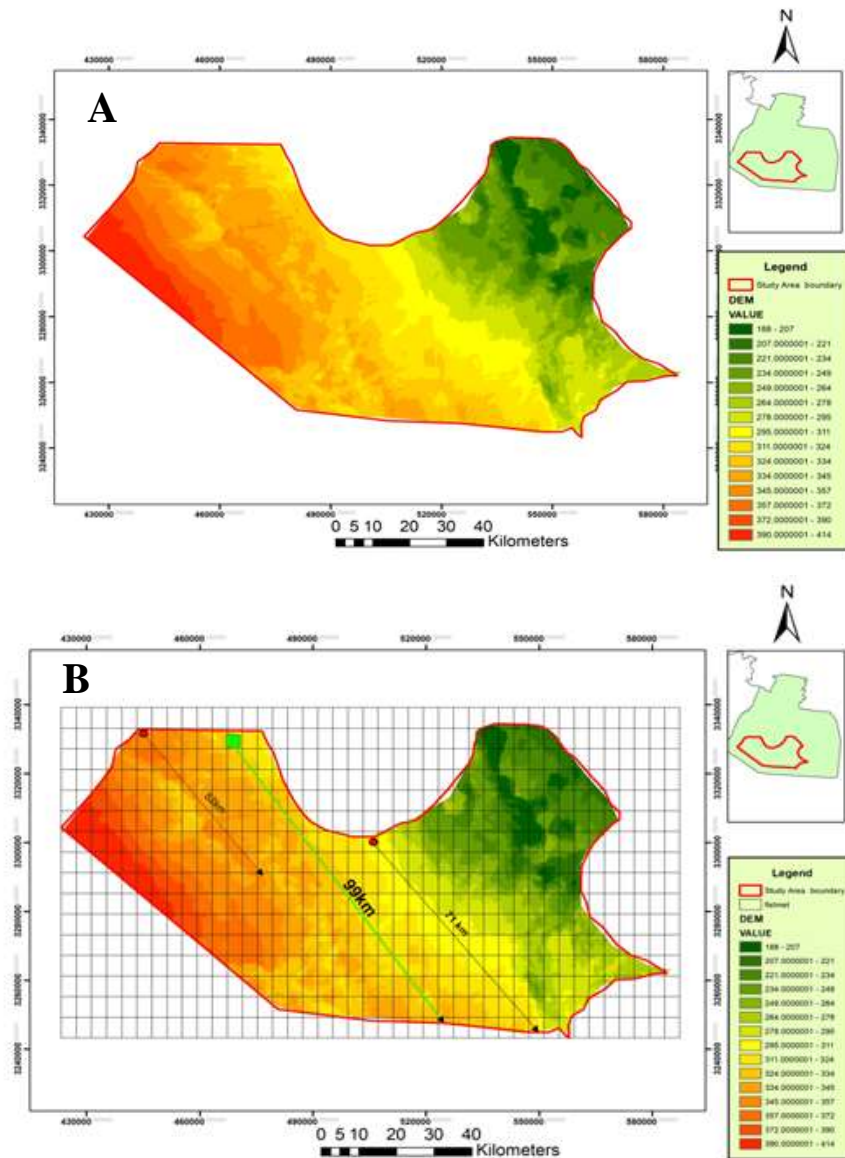


Figure 4: **A)** The topography of AL-Muthana governorate indicated the area’s height and flatness measured in meters, the color ranges from the minimum value (green) to the maximum (red). **(B):** Fish net model of topography in AL-Muthana governorate, the line presents the most suitable space for flat land to install a radio

The SWOT model parameters represent an essential tool in studying the possibility of making the most appropriate choice from a set of correct and feasible options. Strength, for instance, contributes to distinguishing the establishment of the project in one place from the others, according to its percentage in that region. Weakness, on the other hand, shows signs of weakness in the project because it represents the deficit that affects it and prevents it from achieving its objectives. While the opportunity and threat present the external factors related to the project and they reflect the positive effects that help in achieving the desired goal, such as the number of buildings surrounding the place that cause radio interference or the security factors that have a role in the safety of installing radio stations in a specific area. Each of these

parameters (strengths, weaknesses, opportunities, and threats) and their weights (5) have been determined using the SWOT model, tabulated in table 2, to examine the appropriate planning strategies for the areas under study.

Table 2: The obtained results of strength, weakness, opportunity, threat, and their weights (5) from the SWOT model for Nineveh, Al-Anbar, Al-Najaf, and Al-Muthanna governorates

Governorate	Strength	Weight (5)	Weak	Weight (5)	Opportunity	Weight (5)	Threat	Weight (5)
Nineveh	Temperature around (21°)	4	Topography (173-308m)	5	Transportation	3	The security component	4
							Population (3,270,400)	5
			Relative humidity (46.25)	5	Communication towers	4		
							Number of buildings	3
Al-Anbar	Topography (339-854m)	3	Temperature around (23°)	5	Transportation	3	The security component	4
							Population (1,561,400)	5
			Relative humidity (46.25)	5	Communication towers	5		
							Number of buildings	4
Al-Najaf	Topography (8-420m)	4	Temperature around (24.4)	4	The security component	4	Transportation	5
							Population (1,285,500)	4
			Relative humidity (36.5)	4	Number of buildings	3	Communication towers	3
Al-Muthana	Topography (188-414)	5	Temperature around (24.1)	3	The security component	3	Transportation	4
			Relative humidity	4	Communication towers	4		
							Number of buildings	2

Result and Discussions

From the obtained results, it was shown that the optimal location for erecting a radio telescope in Iraq was within four governorates (Nineveh, AL-Anbar, Al-Najaf, and Al-Muthanna), from all topographical, geographical, and climatic perspectives. This conclusion was reached through the application of the SWOT model by placing all external and internal influencing factors of the studied areas, the adoption of urban planners in analyzing the data,

and determining the strengths, weaknesses, opportunities, and threats associated with each planning strategy. We considered addressing each factor that influenced the construction of radio telescopes in these governorates. It was found that the governorate of Nineveh, with a temperature of 21 C°, had the strongest parameter according to the air temperature fluctuation perspective. While based on the relative humidity, the strongest parameter was found in Al-Najaf and Al-Muthanna with values of 36.5 and 36, respectively. As for the landscape, the average height of land in Nineveh governorate reached (173-308m), although it was a weakness due to its flatness. As for the terrains of Al-Anbar, Al-Najaf, and Al-Muthanna, their elevations ranged as (339-854m), (8-420m), and (188-414m), respectively, but the adaptability of their soil was their greatest asset. In our analysis, we utilized data from the Ministry of Planning to establish which roads led to the region were the best. These weights and the number of structures surrounding the property, that can have an adverse effect, were assigned. Regarding the security situation, each governorate in the research region was assigned a weight based on its security status. This was accomplished by communicating with security agencies. It was evident from the statistics that the majority of the population resided in the governorates of Nineveh (3,270,400), Al-Anbar (1,561,400), Al-Najaf (1,285,500), and Al-Muthanna (719.1), except Al-Muthanna, which represented an opportunity. In conclusion, taking all these factors into account, it was found that the most suitable area for installing a radio telescope in Iraq is located in Al-Muthanna governorate as a result of several factors including: the flatness of the land in this area made it the most suitable for installing telescope antennas; the population decline in the governorate, which plays an influential role in reducing noise and interference factors in this area; from a climatic perspective, it is also suitable in terms of low humidity and the wind speed that is not so high as to affect the installation of antennas; in addition to the security aspect, which is found to be appropriate from this point of view.

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