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Using GIS Spatial Analysis for Examination the Utility of the Suggested Suitability Energy Farms Over Kirkuk City

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A B S T R A C T

Global electricity demand is rising, prompting increased attention to renewable energy sources like solar power. This research focuses on identifying suitable areas for power lines connecting solar farms to distribution stations in Kirkuk City. Data types, including urban areas, industrial zones, farms, water bodies, and archaeological sites, were analyzed using GIS-based spatial tools. The study highlights accessible and inaccessible regions of Kirkuk's electricity transmission infrastructure, providing insights for decision-makers. The analysis categorizes areas as either benefitted or unbenefited in the context of solar farm suitability. An important consideration is the need for additional electrical distribution stations to accommodate energy transfer from these solar farms.

1. Introduction

Electrical power production is critical to the prosperity and growth of every country on the face of the universe. Global demand for electricity is increasing in both established and emerging economies [1]. Solar energy represents one of the most important renewable energy sources, and various initiatives have been carried out to ease site inspection and potential assessment. Because the cost of constructing solar energy stations and panels is so high, there is a lot of research being done on remote sensing and GIS technologies [2].

Researchers applied remote sensing and geographic information systems (GIS) to investigate renewable energy resources in order to achieve a more sustainable future [3]. With a high geographical resolution, GIS has gained popularity as a tool for visualizing and analyzing the potential for renewable energy availability [4]. Because the route layout of transmission lines is strongly related to geographical variables, the use of GIS when combined with multi-criteria evaluation methodologies can result in time and cost savings for the planning process [5].

The importance of overhead power transmission line routing is increasing due to rising energy consumption and increased focus on environmental and social problems. Traditional power transmission line route selection techniques are a costly and time-consuming operation in terms of work overload and detailed study of the route selection problem [6]. Nowadays, it is widely acknowledged that the GIS is the most effective tool for solving engineering challenges, particularly path-finding and site-placing issues [7].

GIS spatial analysis provides a complete framework for evaluating the viability of possible energy farm locations by including geographical and environmental aspects into the decision-making process [8]. GIS was utilized as a tool in this study to assess the fundamental parameters in the process of identifying the lands through which power transmission lines could pass from the suggested solar farms to the electrical power distribution stations in Kirkuk. In other words, the main objective of this study is to determine the accessible locations for electric power lines that transit from the source (solar farms) to the electric power distribution stations.

2. Study area

Kirkuk City, situated 286 kilometers north of Baghdad, Iraq's capital, occupies a pivotal role within the nation's socio-economic and historical framework. Encircled by the governorates of Tikrit to the south and southwest, Erbil to the north, and Sulaimaniyah to the northeast, Kirkuk covers an expansive 9679 square kilometers between longitudes 44°10' to 44°30' E and latitudes 35°20' to 35°32' N. The population of Kirkuk Governorate is approximately 1,600,000 people.

Kirkuk's significance is multifaceted. It boasts abundant subterranean resources, notably oil and gas deposits, contributing substantially to the city's economic development and Iraq's energy production. The region's fertile agricultural plains have historically supported robust agricultural activities, enhancing economic prosperity and food security. The city's strategic geographical location further underscores its importance, serving as a critical junction connecting northern and central Iraq, facilitating trade and commerce. Additionally, Kirkuk is steeped in cultural heritage, with the Kirkuk Citadel, dating back to 850 B.C., as a prominent historical site, symbolizing the city's enduring significance. In scholarly research, comprehending Kirkuk City's diverse attributes is essential for a comprehensive understanding of its role in the broader Iraqi context. Figure 1 states the study area (Kirkuk City).

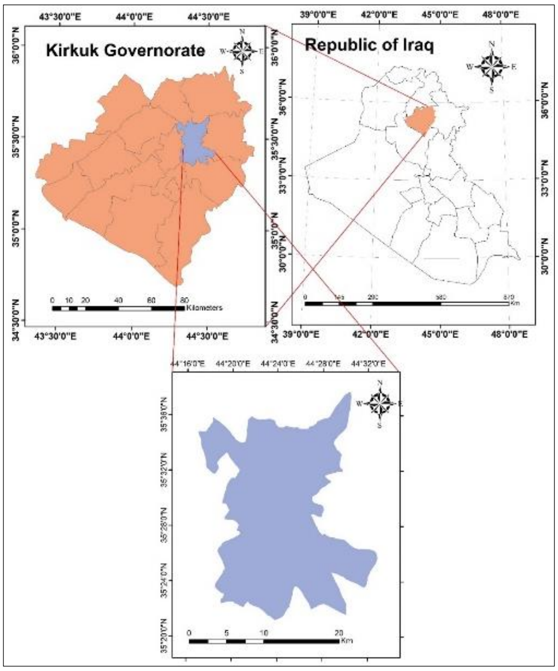

Fig. 1: The research study area (Kirkuk City).

3. Methods and Materials

The fundamental function of a computer-assisted geographic information system is spatial analysis [9]. ArcGIS desktop, developed by the Environmental Systems Research Institute (ESRI), is the most widely used software for mapping and spatial analysis [10]. The use of GIS for land resource planning and decision making has increased in popularity, and it is currently used for an extensive variety of applications [11]. This section details the methods and essential data were used to analyze the utility of the proposed suitability energy farms above Kirkuk City and determine the best locations for rerouting the electric power lines from the solar farms to the primary and secondary power distribution stations. The flowchart in Figure 2 outlines the spatial analysis methods using GIS, beginning with the merging of the important variables (factors) to assess the constraint regions. Then, to define the entirety of the accessible regions, the restricted zones were removed from Kirkuk City's entire territory. After then, access between potential solar farms across accessible transport zones will be tested. Finally, determined the benefits and drawbacks of recommended solar farms.

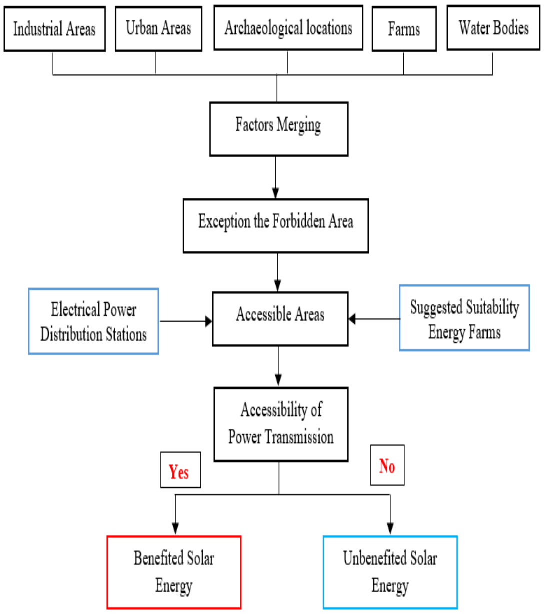

Fig. 2: Flowchart of examination the utility of suggested solar energy farms

3.1 Factors

The data set used in the present study were represented by the factors in form of shapefiles provided by Kirkuk's Urban Planning Department. These layers contain urban areas, industrial zones, farms, water bodies, and archaeological sites. The validity of these layers was confirmed using a high-resolution aerial photograph of Kirkuk, and the appropriate editing were made. The following are the factors used with their distance analysis:

3.1.1 Archaeological buffers

Figure 3 refers to a paramount role within the realm of archaeological site localization and its implications for the Kirkuk municipality. By delineating a 500-meter buffer zone as a constrained area, this figure emerges as an instrumental component in the scientific assessment aimed at ascertaining regions that are amenable for power transmission infrastructure deployment. This demarcation is fundamental in ensuring both the preservation of historical heritage and the effective expansion of vital power transmission networks within Kirkuk's urban jurisdiction.

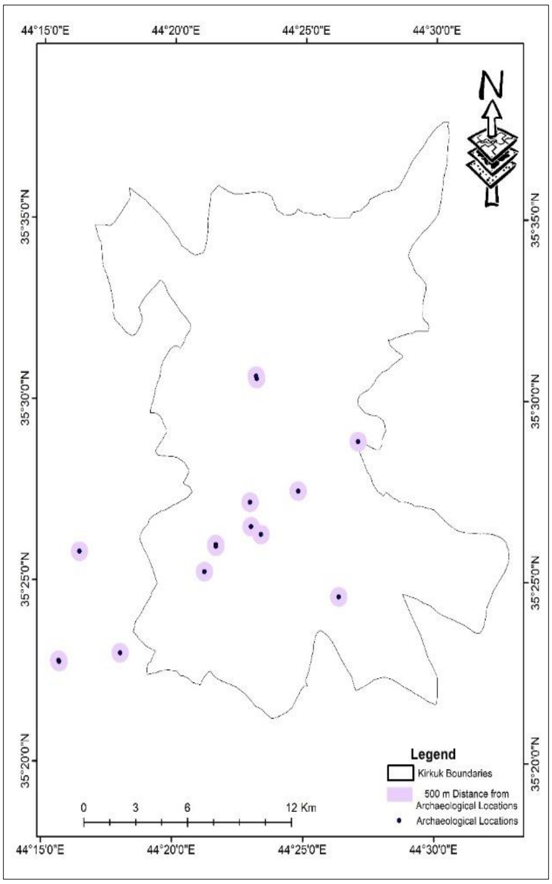

Fig. 3: The distance of 500 m from archaeological sites over Kirkuk City.

3.1.2 Farms buffers

Figure 4 offers a comprehensive visual representation of agricultural expanses and substantial green spaces (farms) within the confines of Kirkuk city's administrative jurisdiction. Leveraging the GIS technology, a buffering analysis with a 100-meter radius is applied, depicting the surrounding region in a light green hue, while the primary agricultural expanse is denoted by a darker green shade. This figure plays a pivotal role as a contributing factor in the rigorous scientific assessment of accessible zones pertinent to the planning and execution of power transmission infrastructure. It underscores the significance of considering the agricultural landscape in the strategic development of power transmission systems within the city of Kirkuk.

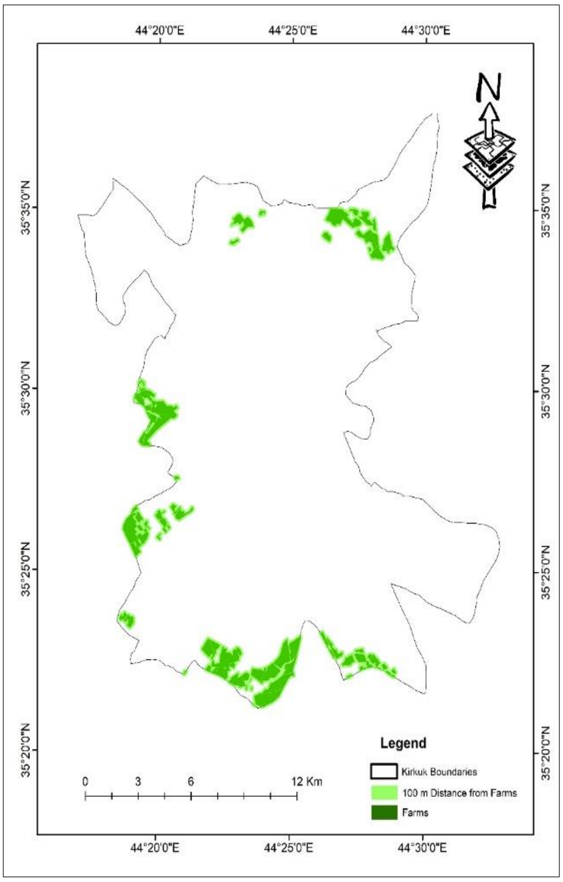

Fig. 4: The distance of 100 m from farms over Kirkuk City.

3.1.3 Farms buffers

Figure 5 provides a graphical representation of industrial areas located within the territorial confines of Kirkuk city's administrative boundaries. Utilizing GIS methodology, a precise buffering operation with a radius of 500 meters is executed, delineating the surrounding areas in a light-colored overlay, while the primary industrial zones are distinctly presented in a dark brown color. This figure holds substantial significance as a contributing factor in the scientific inquiry aimed at defining areas accessible for the strategic planning and implementation of power transmission infrastructure, with particular attention to the 500-meter buffering distance as a critical parameter. It underscores the essential consideration of industrial landscape characteristics in the deliberate planning of power transmission networks within Kirkuk city.

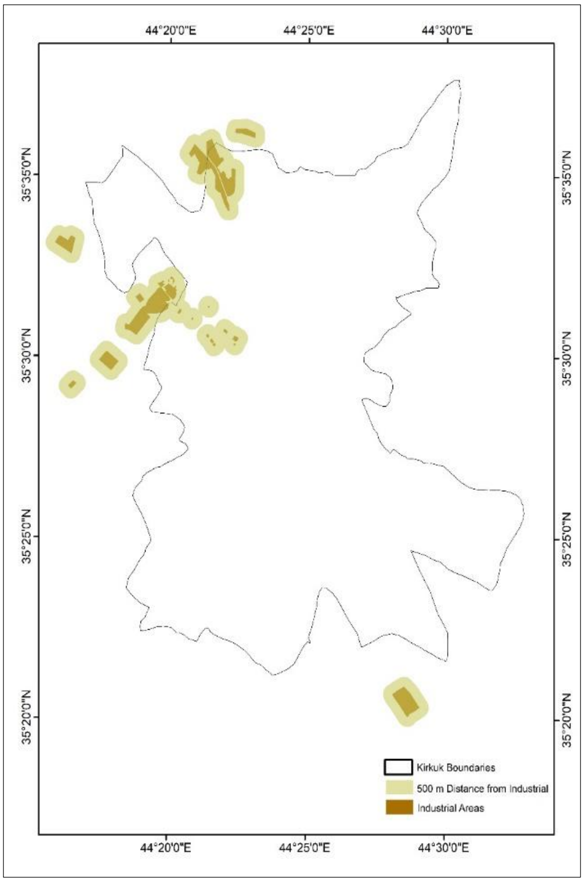

Fig. 5: The distance of 500 m from industrial areas over Kirkuk City.

3.1.4 Water bodies

Figure 6 offers a cartographic depiction of aquatic environments (water bodies) within the administrative boundaries of Kirkuk city. Utilizing GIS tool, a meticulous 100-meter buffer analysis is applied to portray immediate surroundings in a light blue tint, while the central water body areas are distinctly represented in a deeper shade of blue. This visual presentation holds paramount importance as a decisive element in the scientific investigation aimed at defining areas suitable for the strategic expansion and implementation of power transmission infrastructure.

It underscores the need for heightened awareness of water bodies, given their essential role not only as environmental features but also as factors that significantly influence the thoughtful planning of power transmission networks within the Kirkuk City domain.

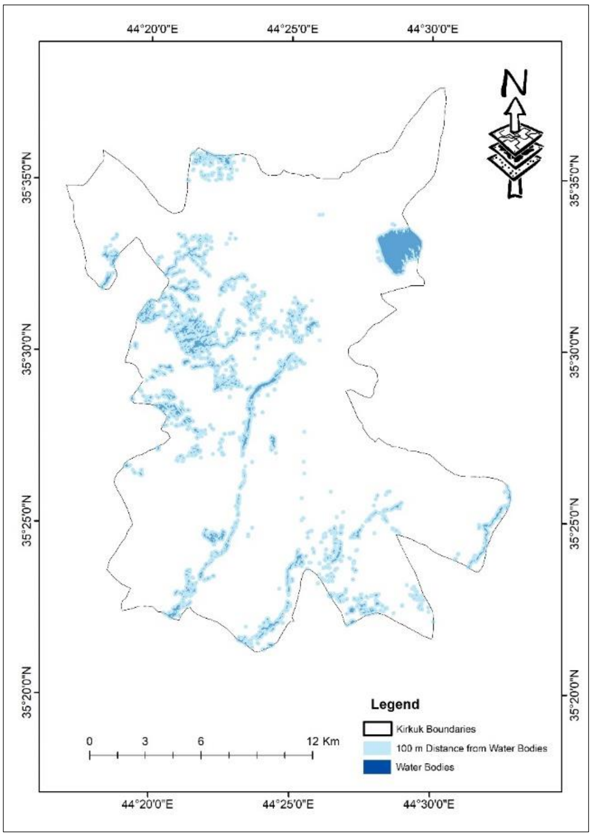

Fig. 6: The distance of 100 m from water bodies over Kirkuk City.

3.1.5 Urban areas

Figure 7 presents a comprehensive geospatial representation of the Kirkuk region, meticulously crafted using (GIS) technology. This detailed illustration serves as an invaluable resource for power line planning, encompassing administrative boundaries, solar farms, power distribution stations, and substations. The figure not only provides a visual overview of the study area but also offers crucial insights into the administrative and geographical landscape of Kirkuk, a critical component for conducting a thorough analysis.

The figure effectively highlights the importance of considering urban and residential areas during power line planning. It underscores the necessity of strategically avoiding urban areas within the administrative boundaries. This decision is driven by multifaceted factors, including the imperative to safeguard densely populated regions, minimize potential disruptions to urban infrastructure, and preserve the aesthetic and environmental integrity of urban environments.

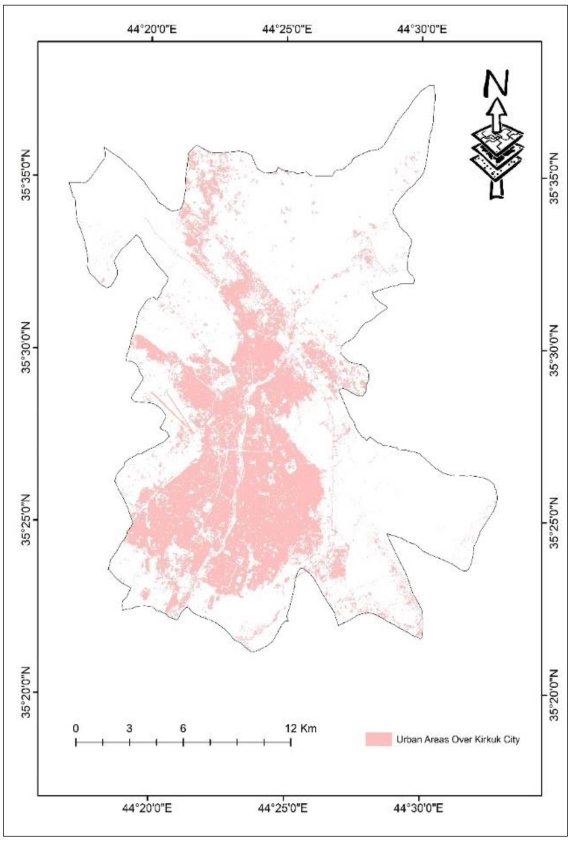

Fig. 7: Urban lands over Kirkuk City.

3.2 Accessibility areas

The delineation of accessible and inaccessible areas for establishing a power line access path, originating from the primary power provider at a solar panel farm and extending to distribution stations and substations, requires consolidating various critical considerations. These considerations summarize the constraints that pertain to identifying unavailable areas, the subsequent exclusion of these regions from the overarching spatial analysis, and the utilization of a Multi-Criteria Decision Analysis (MCDA) framework within (GIS) domain. The overarching objective is to produce a conclusive representation of the suitable areas for deploying power lines, thereby facilitating a judicious and data-driven decision-making process in the context of power infrastructure planning.

4. Results and discussions

4.1 The accessibility areas

Figure 8 provides a visual representation of the boundaries of Kirkuk city, illustrating areas marked as accessible and inaccessible in the context of establishing power transmission pathways from a solar panel farm to a distribution power station. The depicted figure is the outcome of GIS analysis, incorporating a comprehensive spectrum of relevant considerations. The analytical approach employed in this study results in a clear depiction of the feasibility of routes for the installation of power transmission lines. Regions classified as accessible are represented by a grey pattern, while those deemed inaccessible are visually depicted through a yellow pattern. The scientific intention behind this presentation is to offer a transparent, data-driven understanding of the available corridors for power transmission in the specified locale.

For a more comprehensive overview, it is important to note the total area of Kirkuk's administrative boundaries, which measures 387,859,224.355 m². Within this extensive area, the accessible region for power transmission covers 211,377,347.186 m², while the inaccessible areas amount to 176,481,877.169 m². This detailed breakdown of the administrative boundaries and the corresponding accessible and inaccessible areas provides valuable insights for decision-makers and stakeholders involved in the planning and implementation of power transmission infrastructure in Kirkuk.

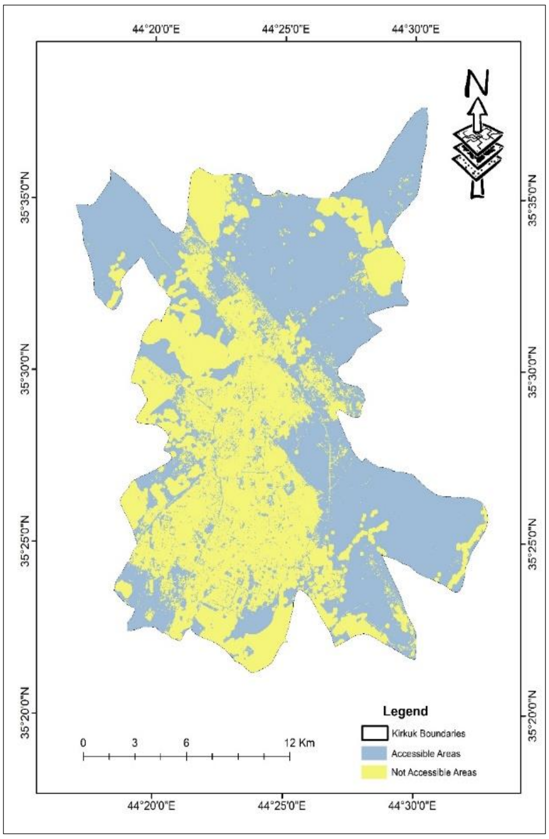

Fig. 8: The accessible and inaccessible for power transmission from a solar panel farm to distribution power station over Kirkuk City

4.2 The benefit of solar farms

Figure 9 represents the culmination of an extensive research effort aimed at the systematic evaluation of available sites for the establishment of solar farms. This comprehensive assessment integrates a wide array of pivotal factors, encompassing urban, industrial, water bodies, archaeological, and agricultural considerations. The total suggested area for solar farm development is 11,790,200 m². The result of this rigorous analysis involves the delineation of areas categorized as either "benefited," illustrated in magenta (covering 10,943,875 m²), or "unbenefited," depicted in red (covering 846,325 m²), in the context of solar farm suitability. These delineations are explicitly situated within the administrative confines of Kirkuk city and are derived from a thorough GIS mapping and analytical procedure.

Of notable significance, this figure prominently underscores the strategic placement of distribution power stations within Kirkuk city, distinctly marked in black. The synthesis of these crucial insights leads to the formulation of a recommended power transmission route, denoted in blue, effectively connecting solar farms, acting as power sources, to the nearest distribution power station. This figure encapsulates a comprehensive methodology, aligning geospatial intelligence with pragmatic considerations, thereby providing a robust scientific foundation for the strategic planning and execution of solar energy infrastructure within the context of Kirkuk city.

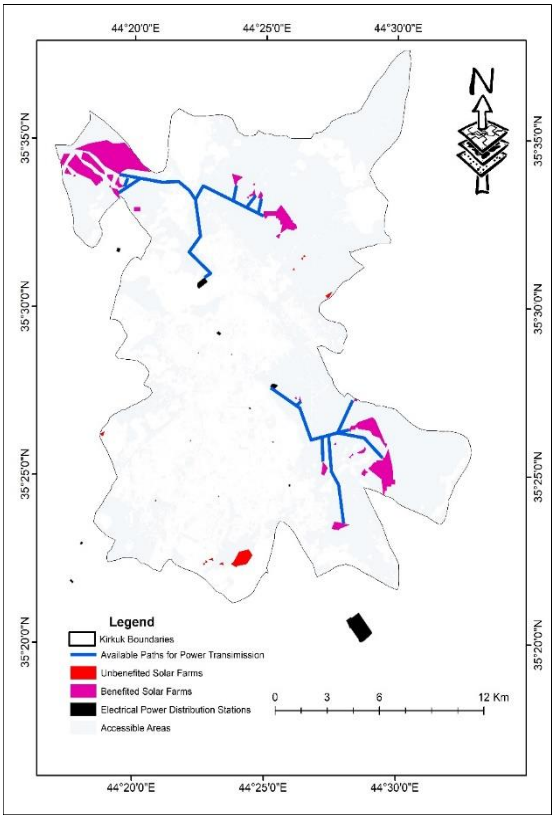

Fig. 8: Available lands for solar energy farms surrounding Kirkuk City

5. Conclusion

Combining spatial data sets and analytical tools has improved comprehension of the complicated relationship between geographical characteristics, land use structure, and renewable energy ability, resulting in enhanced decision-making. The accessible and inaccessible areas of Kirkuk's power transmission infrastructure are 211,377,347.186 m² and 176,481,877.169 m², respectively, providing crucial insights for decision-makers and stakeholders. In the context of solar farm suitability, the result of this thorough investigation is the demarcation of regions classified as either benefitted, represented in magenta spanning 10,943,875 m², or unbenefited, which covers 846,325 m². The results from the process of finding the most suitable location for solar farms will be of benefit, as there is another step that must be taken into consideration, which is, is it possible to transfer electrical energy from these solar farms to the existing electrical distribution stations? Therefore, to take advantage of all the suitable places by establishing other electrical distribution stations.

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