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Towards advanced sustainable criteria for choosing the best site for collecting solar energy in cities using multi-criteria GIS

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Abstract

Solar energy has become a prominent and crucial source of clean energy due to the increasing global demand for electricity. There is a prevailing global trend towards the construction of solar farms as a means of energy generation. This study aims to assess multiple criteria encompassing urban, environmental, and social aspects in order to ascertain the optimal site for constructing solar farms. The evaluation primarily focuses on characteristics such as topography, solar radiation, accessibility, land use, and proximity to roads and power stations. In order to acquire the necessary spatial fit model, the data was evaluated utilizing a Geographic Information System (GIS) program, and the criteria were subsequently consolidated into an integrated geographic information system. A comprehensive review of the existing body of literature reveals that environmental factors, specifically solar radiation and aspect, play a crucial role in determining the suitable places for the establishment of solar energy collection projects (Merrouni et al. in Energy Procedia 49:2270-2279, 2013; McKinney in J Student Res Environ Sci Appalac 4:1-14, 2014). Furthermore, other analysis factors such as proximity to built-up regions, closeness to power lines, and proximity to roadways are taken into account (Hott et al. in GIS-based Spatial Analysis For LargeScale Solar Power And Transmission Line Issues: Case Study of Wyoming, U.S. In: Proceedings of the 41st American Solar Energy Society Meeting, 2012; Effat in Int J Adv Remote Sens GIS 2:205-220, 2013). These criteria have an impact on the cost of solar farms. The objective of this study was to assess several aspects influencing the selection of an optimal location for a solar energy farm, taking into consideration the aforementioned criteria. The study was carried out in New Aswan city, utilizing data obtained from the Urban Planning Authority within the Ministry of Housing and Urban Development, as well as the New Aswan City AuthorityI generated cartographic representations and compiled quantitative data, which informed our selection of places that met the established criteria through the utilization of a Geographic Information System (GIS) software. Upon the conclusion of the study, numerous locations that satisfied the established criteria were selected. The present study focuses on regions with high capacity, and the findings are depicted in the form of spatial and objective maps. One of the primary benefits associated with the utilization of this methodology lies in its versatility, as it can be implemented across several domains. Furthermore, a straightforward adjustment of the criteria facilitates its application in the selection of optimal locations for wind farms.

Keywords Solar farms, Multi-criteria decision analysis, Spatial analysis, Sustainable, GIS, Solar energy

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Introduction

On April 23, 2009, the European Parliament and the European Council expressed their orientation towards the promotion of energy derived from renewable sources, made the production of clean energy one of the main global goals to be achieved by 2030. Similar to other nations, Egypt is compelled to reduce its electricity generation from traditional energy sources and transition towards utilizing renewable energy sources.

The literature review examines the impact of environmental factors, specifically solar radiation and aspect, on the selection of suitable locations for solar energy gathering projects (Merrouni et al. 2013; McKinney 2014).

Furthermore, supplementary considerations such as proximity to urban centers, proximity to energy lines, and proximity to roadways are also taken into account in the research. These criteria impact the decrease in expenses related to solar farms. Regarding the lowering of costs related to solar farms (Hott et al. 2012; Effat 2013).

The determination of solar farm locations can be categorized into two distinct groups: environmental criteria and economic criteria.

The substantial population growth in Egypt necessitated the establishment of new towns, thus resulting in an increased demand for electrical energy and the emergence of the need for new energy sources.

The European Parliament and the European Council issued directives on November 24, 2010 regarding Egyptian relations with the European Union. These directives highlight the long-standing relationship between Egypt and the European Union, particularly through the partnership agreement that has been in effect since 2004. This partnership facilitates cooperation and cultural exchange, providing Egypt with the opportunity to benefit from the experience of the European Union. While these directives are not mandatory, they emphasize the importance of preventing and controlling pollution, specifically in relation to industrial emissions. It is imperative to restrict the production of energy obtained from environmentally detrimental sources and decrease carbon dioxide emissions.

Literature review

This section presents a comprehensive review of the literature on solar energy resources worldwide and the advantages it offers, as assessed by consumers of nonrenewable resources, from 2010 to 2019.

According to Jacobson et al. (2011), this article examines the viability of supplying global energy needs through the utilization of wind, water, and sunshine. Part one of the discussion focuses on the characteristics of the WWS (wind, water, and solar) energy system, the existing and future need for energy, the availability of WWS resources, the quantity of WWS devices, and the requirements for area and materials. Part two of the text focuses on the aspects of variability, economics, and politics related to WWS energy. Ultimately, they propose achieving complete energy production with WWS by 2030 and completely replacing the current energy sources by 2050.

According to Damon and Vasilis (2011), this research aims to enhance the comprehension of the environmental consequences associated with the installation and operation stages of solar electricity. They have identified and evaluated 31 consequences associated with land use, human health and well-being, wildlife and habitat, geohydrological resources, and climate. Their analysis achieves the following. The process involves: (1) identifying the effects, (2) evaluating each effect in comparison to conventional power generation, (3) categorizing each effect as either advantageous or disadvantageous, and (4) determining the importance of each effect. The results provide a thorough depiction of the effects of installing and operating solar power systems in different climates. They also offer an initial understanding of the effects of solar.

According to Fude et al. (2012), this review article provides a comprehensive and innovative analysis of the challenges related to energy conversion cells. The authors examined various energy conversion pathways for converting solar energy into electrical energy and presented a concise illustration of the energy conversion process. The authors subsequently examined the operational principles of solar cells, specifically focusing on the processes of charge carrier production, separation, and transport/collection. A study was conducted to compare various energy conversion cells, such as solar, thermoelectric, electrochemical, and photoelectrochemical cells. The study focused on examining the operating principles of each type of cell. The functioning principles of both cells were demonstrated to be remarkably similar, adhering to a straightforward energy conversion model. This article aims to examine the intricate relationships among various energy conversion cells and the underlying essence.

According to Nagalakshmi et al. (2013), this research presents an effective energy distribution system for the allocation of energy supplied from renewable sources. To address the current challenges, it is necessary to ensure a consistent supply of energy generated from renewable sources. The device was linked to a battery and inverter. This research has successfully developed and implemented a prototype system to demonstrate the proposed principles. The initial testing indicate that this approach holds great potential for practical implementations. The drawback with this system is that it requires a massive converter to store the highly fluctuating solar energy and its upkeep. This can be addressed by the government through the construction of solar grids that run parallel to the existing grids.

According to Chinnammai (2014), this article explores the energy deficit and investigates the societal advantages of utilizing solar energy. In order to gain a comprehensive understanding of solar energy, the individual conducted a thorough examination of the existing literature

Fig. 1 Perspective layout of city of Malmo (source: Dowding E., 2021)

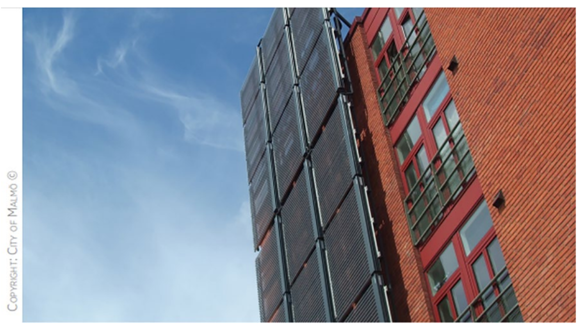

Fig. 2 Tegelborgen solar collector (source:Dowding E., 2021)

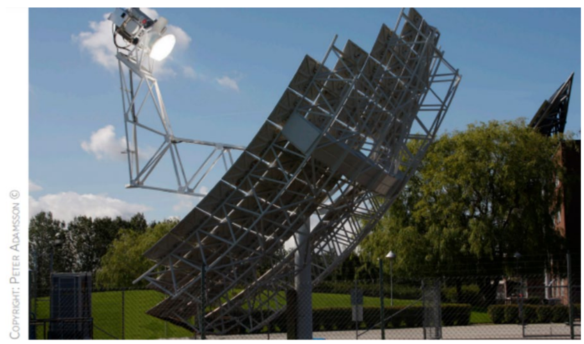

Fig. 3 Solar Stirling Engine (source: Dowding E., 2021)

on the subject. This involved exploring different viewpoints on the current state of conventional energy, power generation, and the overall status of renewable energy. Additionally, the individual sought to grasp the broader concept of renewable energy and specifically focused on solar energy. He reached the conclusion that solar energy is the optimal energy source for human life.

According to Bou-Rabee et al. (2015), the authors conducted a study to analyze the specific properties of solar energy radiation in Kuwait. They measured the irradiance and compared the results from specified time intervals in two contrasting seasons. The study found that the daily fluctuation in irradiance during winter was approximately 6.5 times more than during summer, with a percentage of 31% compared to 4.8% respectively. Undoubtedly, solar power producing systems in the vicinity would see substantial daily variations during the winter season. Consequently, this would require regular utilization of backup power sources to fulfill the demand for electrical power.

According to Emetere et al. (2016), this work aims to address the issues caused by solar shading in the coastal zone, which result in anomalies in solar radiation. This study conducts a comparative functional investigation of two randomly selected types of photovoltaic solar panels. The photovoltaic panel underwent testing under varying solar radiation conditions observed in the southwestern area of Nigeria. A mathematical model was proposed to describe the issues faced by solar energy operators in areas with high costs. Scientific evidence has demonstrated that climatic conditions have a direct impact on solar radiation in coastal areas, as confirmed using both analytical and numerical methods. Consequently, the efficiency of solar photovoltaic systems would be significantly impacted. A feasible approach to improve the efficiency of solar photovoltaic systems in coastal regions was offered by introducing electronic concentrator pillars in a planned solar farm.

According to Abdullah et al. (2017), this article evaluates the degree of consciousness, implementation, and obstacles associated with solar PV systems in Akure. The assessment is conducted on a sample of 150 residential structures, selected randomly, using a structured questionnaire provided to the occupants/owners. The results indicated that a significant proportion of

Fig. 4 Solar farm in Masdar city 2009 (Source: Annual Report 2022)

Fig. 5 Solar cell farm in Masdar city

Fig. 6 Solar farms to generate electrical energy in Masdar city 2019 (Source: Annual Report 2022)

residential buildings rely on diesel/petrol generators as a substitute for the national power grid. Additionally, the study found that there is a low level of awareness regarding solar photovoltaic systems. However, there is a strong willingness to adopt these systems, but the main obstacle is the high cost associated with implementing them. The study findings add to the expanding body of research on the adoption of renewable energy for power generation. They emphasize the significant obstacles that impede the successful implementation of this beneficial solution. Additionally, it offers a potential market for individuals interested in the solar energy industry.

According to Farhad et al. (2018), this research investigates the impact of wage, interest rate, exchange rate, and oil price on the price of solar modules in five prominent solar module producing countries. They primarily focused on examining the potential economic elements that could provide us with new understanding of the process behind the recent decrease in costs of solar modules. They determined that utilizing business research and development (R&D) spending as an independent factor could provide a more comprehensive comprehension of the impact of solar R&D on the reduction of technological costs.

According to Samuel et al. (2019), this study presents a survey conducted to examine the level of knowledge and utilization of solar energy as a substitute power supply for ICT systems in library and information centers in Nigeria. This study employed a descriptive research design utilizing the survey method. A questionnaire was created and employed as a survey tool. The study population comprises the personnel of three Nigerian university libraries. In conclusion, this study finds that all the participants possess a strong understanding of solar energy, as seen by their unanimous yes responses.

Countries are actively pursuing the adoption of renewable energy technologies, particularly in the realm of electricity generation. Consequently, countries and international organizations have collaborated to formulate policies aimed at mitigating carbon emissions and facilitating the global transition to renewable energy sources. The subsequent examples serve to illustrate these cooperative efforts.

- Arab Ministerial Council for Electricity/Committee of Experts on Renewable Energy and Energy Efficiency/Arab Strategy for Renewable Energy Applications

The Arab Ministerial Council for Electricity of the League of Arab States decided in January 2010 to establish a Committee of Experts on Renewable Energy and Energy Efficiency. The council includes experts from Arab countries, ESCWA and other regional organizations. The Arab Ministerial Council for Electricity of the League of Arab States decided in January 2010 to establish a Committee of Experts on Renewable Energy. The council includes experts from Arab countries, ESCWA and other regional organizations. This committee is following up the preparation of the Arab strategy for renewable energy applications, which is expected to be completed before the end of 2010 (Economic and Social Council 2010).

- Mediterranean Solar Plan

The Union announced a Mediterranean solar plan, one of its most important items, to equip the capacity of 20 GW to produce electricity from renewable sources of energy in the southern and eastern Mediterranean countries. Arab countries are expected to take a unified position on this plan (Economic and Social Council 2010).

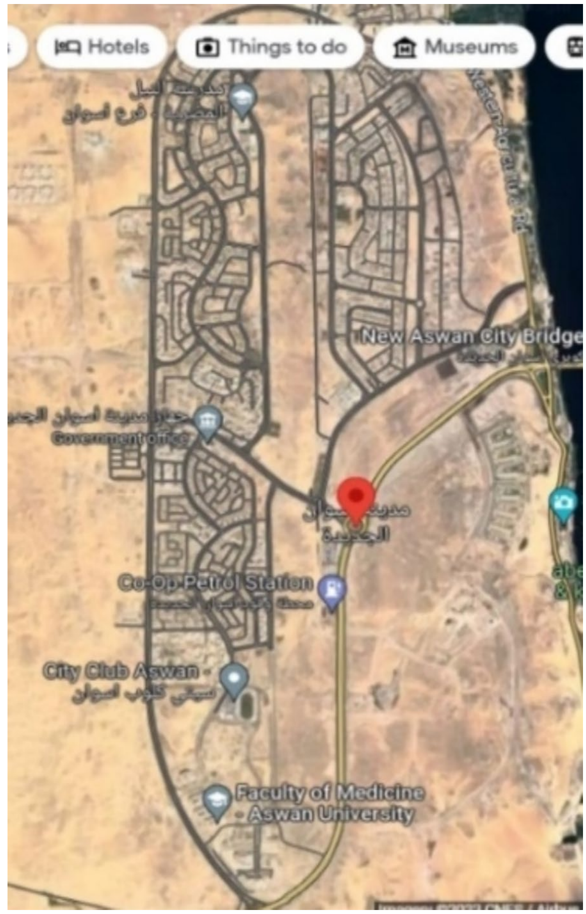

Fig. 7 The location of New Aswan City (Source: google mab)

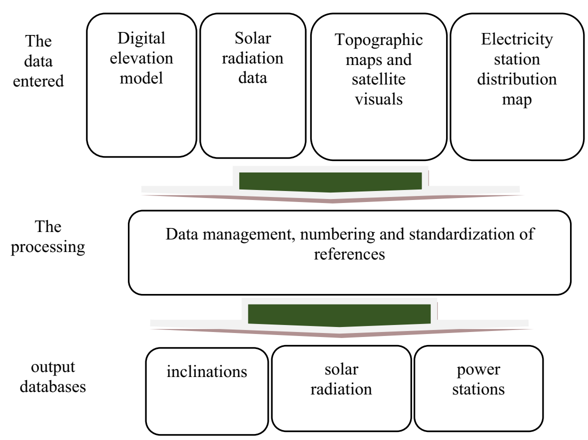

Fig. 8 The methodology for preparing the used databases (Source: The researcher)

Methods

The utilization of multi-criteria data analysis might prove advantageous in facilitating informed decision-making across several domains. This strategy involves the utilization of a collection of methodologies and tools that facilitate the convergence of diverse variables in order to arrive at an optimal conclusion. The integration of multi-criteria analysis with geographic information systems has been employed to facilitate the identification of optimal decisions or site selections. The initial phase of multi-criteria analysis involves the establishment of the selection criteria to be employed (Pokonieczny 2016).

The utilization of Boolean criteria enables the discernment of suitable and unsuitable websites, hence facilitating the determination of a site's appropriateness or Inappropriateness (Tomala et al. 2016). The consideration of environmental factors, particularly solar radiation, plays a significant role in the selection of suitable places for the establishment of solar farms (Merrouni et al. 2013; McKinney 2014).

Moreover, in numerous evaluations, factors such as the closeness to urbanized regions, power stations, and road infrastructure are commonly employed as significant considerations when evaluating the suitability of a place for the establishment of solar farms (Hott et al. 2012; Effat 2013). It is hypothesized that these characteristics may contribute to a reduction in the expenses associated with the construction of solar farms. The location selection for solar farms can be categorized into two distinct groups: environmental considerations and economic factors. I have hypothesized that the identification of the optimal site for the construction of a solar farm involves the selection of suitable areas based on predetermined criteria (Fig. 8). The approach is relied on weighting criteria using AHP (Analytic Hierarchy Process) and WLC (a decision rule for deriving composite maps, using GIS) methods to give priority appropriateness, indicating whether a solar farm site has low, medium or high potential (Hejmanowska and Hnat 2009).

The Analytic Hierarchy Process (AHP) (Basak and Saaty 1993) technique has gained recognition from the global scientific community as a robust and

Fig. 10 The slope of New Aswan Land (Source: The researcher)

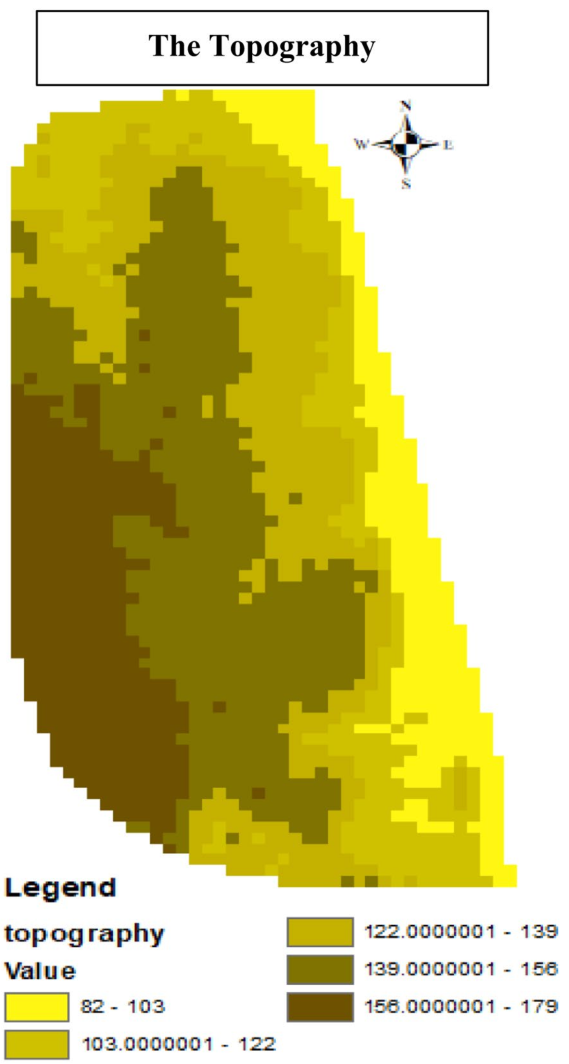

Fig. 9 The Topography of New Aswan Land (Source: The researcher)

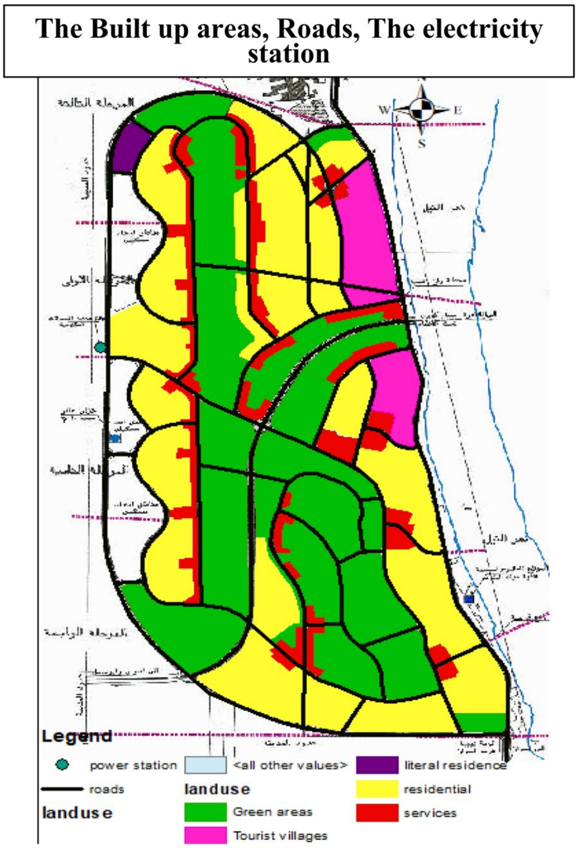

Fig. 11 The built up areas, Roads, The electricity station (Source: The researcher)

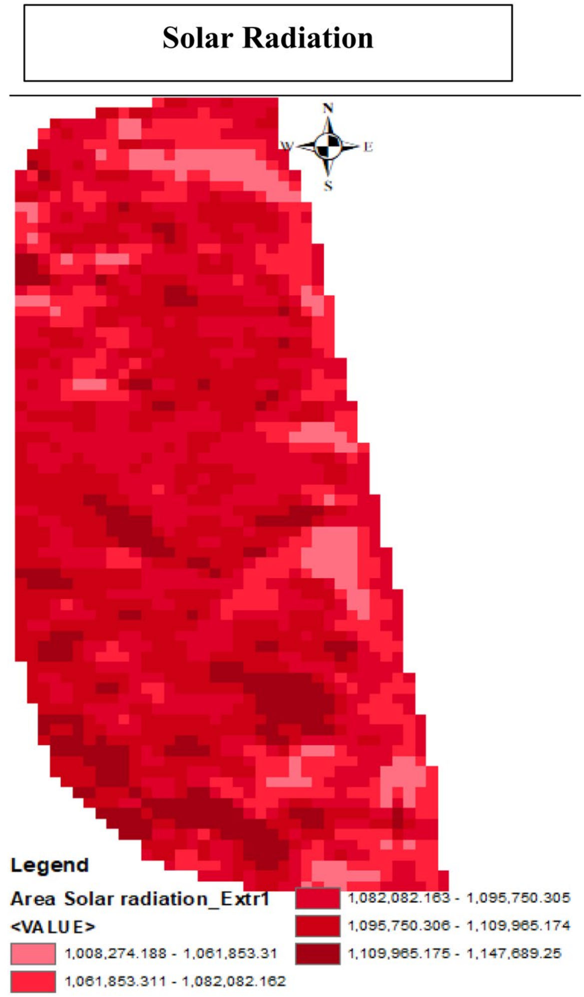

Fig. 12 Annual average of solar radiation (Source: The researcher)

adaptable approach for addressing intricate decision issues involving several criteria. According to the findings of Malczewski (2006), the third most appropriate approach in literature pertaining to multi-criteria decision analysis in the field of Geographic Information Systems (GIS) is identified.

The fundamental components of the Analytic Hierarchy Process (AHP) involve structuring the intricate decision problem into a hierarchical framework consisting of objectives, criteria, and alternatives. Additionally, I concur with the preceding research that recommends evaluating each category within the hierarchy in relation to each criterion on the preceding level. AHP and WLC are considered the optimal selection due to their widespread acceptance among the international scientific community as a robust and adaptable approach for addressing intricate challenges encountered in the decision-making process (Suprova et al. 2020).

Currently, the analysis is contingent upon the determination of the weights of the criteria using the analytical hierarchy process (AHP) (Saaty 1987). Subsequently, the results are standardized and maps are enhanced to visually depict the suitability of different places for the optimal placement of a farm. The analysis comprises two distinct stages: The initial phase involves establishing a hierarchical framework and subsequently assessing the criteria contained inside this framework. The subsequent phase involves doing an analysis of the Analytic Hierarchy Process (AHP) in order to assign weights to the criteria. This is accomplished by evaluating the criteria through pairwise comparisons. The selection of weights is followed by the creation of maps that depict many factors, each assigned different weights according to the Weighted Linear Combination (WLC) approach. The aforementioned approach is often employed as a multiple criteria evaluation method for analyzing the suitability of locations. The methodology involves the process of standardizing the fit maps, assigning material modification weights to

Table 1 Criteria for the most suitable solar collector sites

Criteria type	The criteria	The categories	Proportion of classifications	The suitability	The relative weight
Environmental	The Topography	82–103	0	Not suitable	0.1
		103–122	0	Not suitable	
		122–139	1	Low	
		139–156	2	Medium	
		156–179	3	High	
	The slope	0–1.69	3	High	0.2
		1.69–3.27	2	Medium	
		3.27–5.23	1	Low	
		5.23–8.28	0	Not suitable	
		8.28–13.89	0	Not suitable	
	The distance from power stations	0–1.9	3	High	0.15
		1.9–3.4	2	Medium	
		3.4–4.9	1	Low	
		4.9–6.2	0	Not suitable	
		6.2–10	0	Not suitable	
	Solar radiation	1,008,000–1061000	0	Not suitable	0.35
		1,061,000–1082000	1	Low	
		1,082,000–1095000	2	Medium	
		1,095,000–1109000	2	Medium	
		1,109,000–1147000	3	High	
Economical	The distance from the road network	0–1.5	3	High	0.1
		1.5–2.9	2	Medium	
		2.9–4.24	1	Low	
		4.24–5.5	0	Not suitable	
		5.5–6.9	0	Not suitable	
	The distance from the buildings	0–1.54	3	High	0.1
		1.54–2.89	2	Medium	
		2.89–4.24	1	Low	
		4.24–5.5	0	Not suitable	
		5.5–6.94	0	Not suitable	

these maps, and subsequently combining these weights with the valid standard maps in order to derive an overall fit score (Malczewski 2006). The utilization of the Weighted Linear Combination (WLC) approach in conjunction with the target layer of the excluded sites enables the generation of a spatial representation that assesses the suitability of different places for the establishment of a solar farm. Ultimately, the final phase entails the selection of the optimal site for the solar farm, while duly considering the socio-economic aspects.

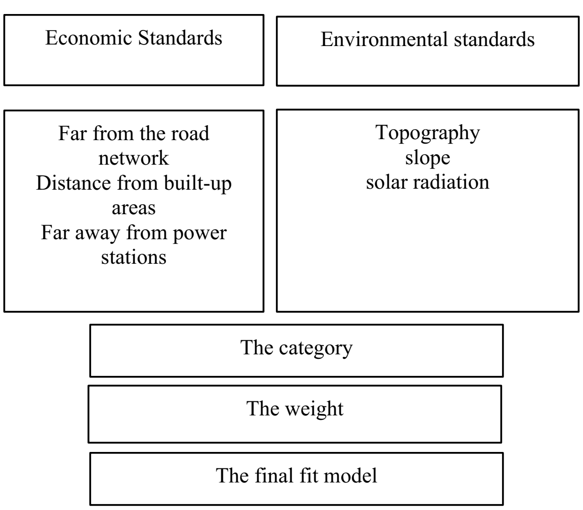

Fig. 13 The methodology for preparing the used databases (Source: The researcher)

Global and Arab experiences

City of Malmo

Malmo is widely recognized as one of Sweden's most progressive cities with regard to sustainable development. The urban area has experienced a significant transformation in its sustainable planning initiatives and efforts to recruit foreign corporations to the locality (Fig. 1).

The initial environmental plan was implemented in 1990, followed by a subsequent plan in 1998. Additionally, efforts were made to enhance the residential neighborhood heating system (Fig. 2). The city of Malmo has set a goal to achieve complete reliance on renewable energy sources, including as solar, wind, hydropower, and biogas. The town now possesses the most extensive solar

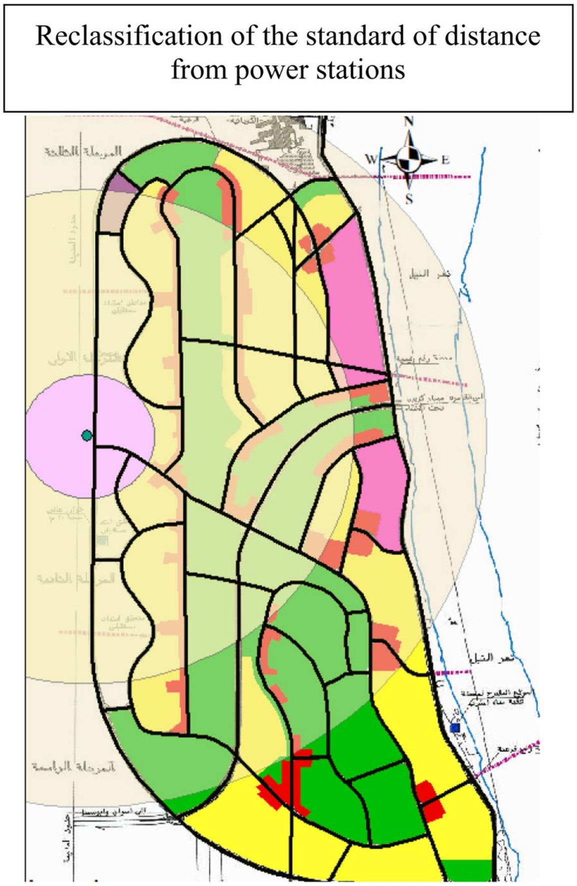

Fig. 14 A model for reclassifying the standard of Distance from power stations (Source: The researcher)

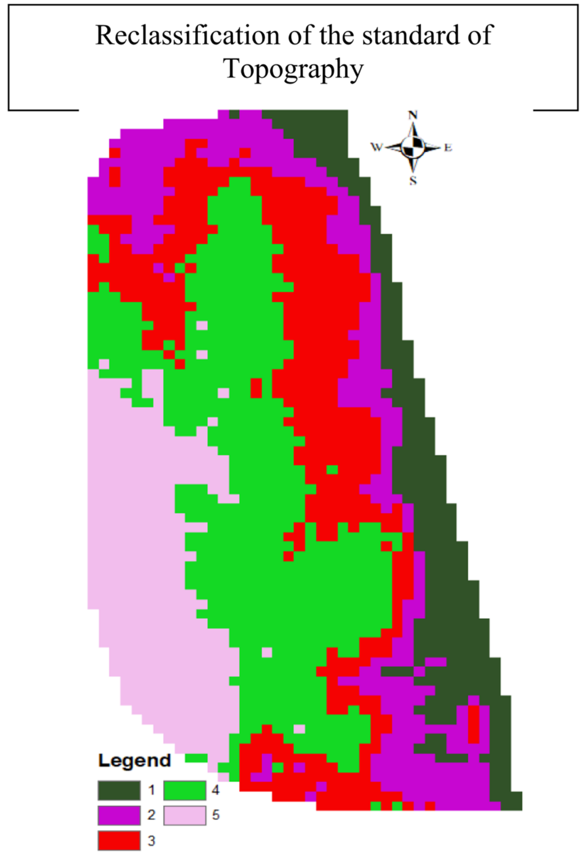

Fig. 15 A model for reclassification the standard of topography (Source: The researcher)

farm in the nation, known as Park Sege. This farm spans an area of 1250 square meters and is about to be outfitted with Sterling's inaugural solar-powered engine (Dowding E., 2021).

Since 2001, the Western Harbour, which is a postindustrial area, has undergone a redesign with the aim of transforming it into a sustainable residential neighborhood. The objective of this redevelopment is to provide renewable energy entirely to a population of 20,000 individuals by the year 2030 (Malmö Stad, 2021d). Based on the findings of Climate Action (2013) and Northern Architecture (2021), the urban development project known as "Bo01" is designed with the objective of achieving complete reliance on local renewable energy sources. To fulfill this aim, the project incorporates solar energy technology, specifically utilizing a solar photovoltaic system spanning an area of 120 square meters, to meet the energy demands of the buildings (Fig. 3).

Masdar City

Masdar City serves as a prominent exemplar of renewable energy generation and distribution, as well as a trailblazer in the realm of service and grid-connected industries, alongside its innovative mini-power systems. The establishment of a 10 MW solar photovoltaic power plant in Masdar City was initiated by the Government in 2009 (Fig. 4).

This project represents the inaugural renewable energy initiative in the United Arab Emirates (UAE) and stands as a pioneering endeavor throughout the Middle East region. The farm plays a significant role in mitigating the annual release of 15,000 metric tonnes of carbon dioxide gas.

In March 2013, Masdar inaugurated "Shams Station1," which stands as one of the largest concentrated solar plants globally and holds the distinction of being the first of its kind in the Middle East and North Africa region. The establishment of a 100 MW thermal solar power plant has been facilitated through a collaboration between Masdar, Total, and Abengwa (Fig. 5).

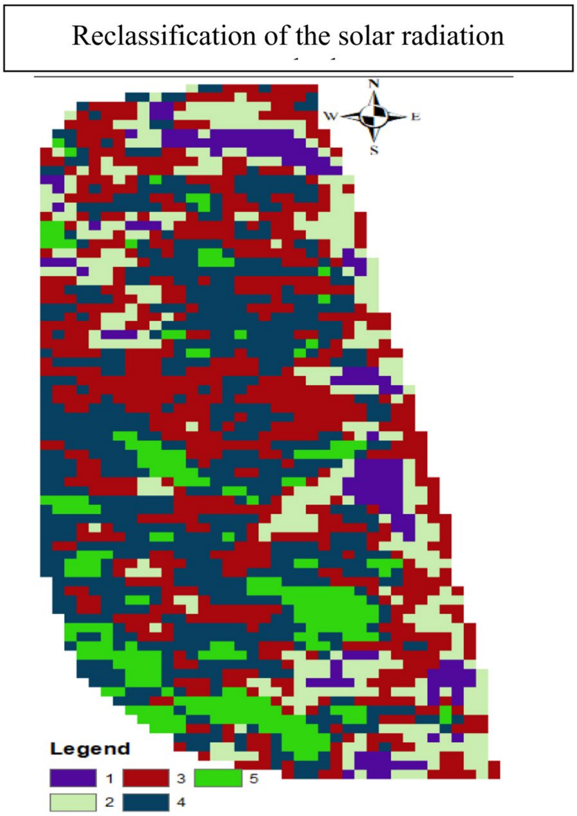

Fig. 16 A model for reclassifying the solar radiation standard (Source: The researcher)

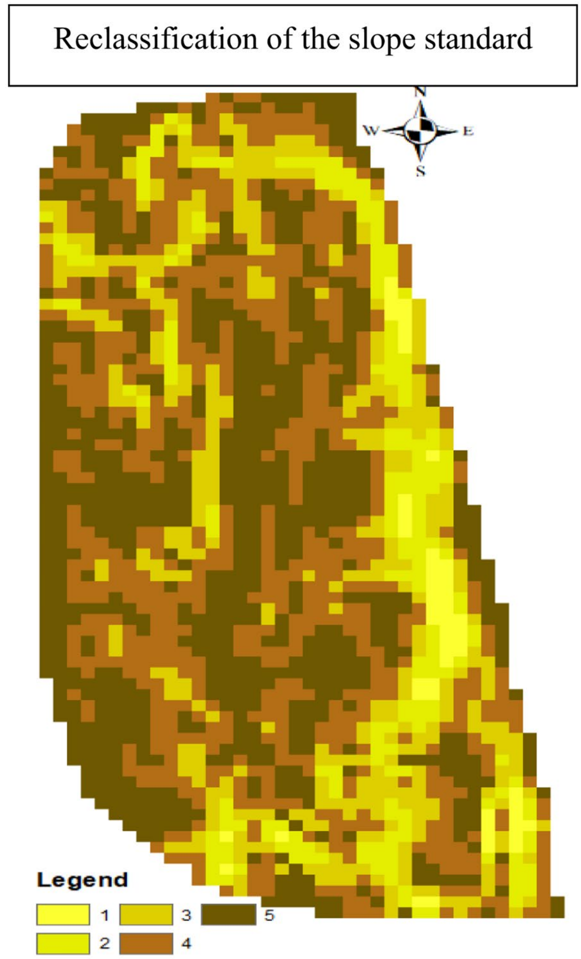

Fig. 17 A model for reclassifying the slope standard (Source: The researcher)

A solar power plant with a capacity of 200 megawatts was constructed in the year 2018. In the year 2019, an additional power plant with a capacity of 300 megawatts was constructed. During the third phase, a power plant with a capacity of 300 megawatts was constructed, facilitating the provision of electricity to around 240,000 households (Fig. 6) (Abu Dhabi Future Energy Company 2022).

The properties of new Aswan city

The objective of the multi-criteria process is to analyze the presence of a collection of criteria within a geographic region and to provide multiple options or alternatives for decision-makers. The approach encompasses three distinct methodologies: overlay analysis, the analytic hierarchy process, and the weighted linear combination method. The initial approach involves ascribing the notion of identifying the intersecting location among multiple layers, each of which serves a distinct criterion, in order to ascertain the spatial site that satisfies all the criteria. This entails evaluating the significance of each criterion and determining the relative importance of the criteria, ultimately leading to the identification of the most appropriate alternatives (Castillo 2016; Abudeif et al. 2015).

The weighted linear synthesis method, which will be utilized in this study, is founded on the principle of determining the weighted average of specific criteria within each cell. This approach aims to establish a practical model by employing the following equation:

$$S = \sum_{i=1}^{n} w_i x_i / \sum w$$

S fit coefficient; Wi weight per standard; Xi coefficient of the criterion number I; n number of standards applied.

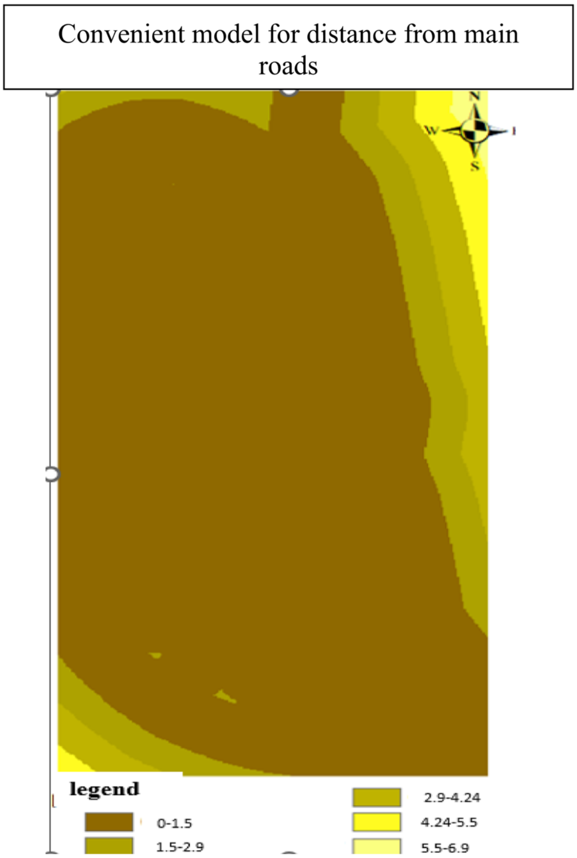

Fig. 18 Convenient model for distance from main roads (Source: The researcher)

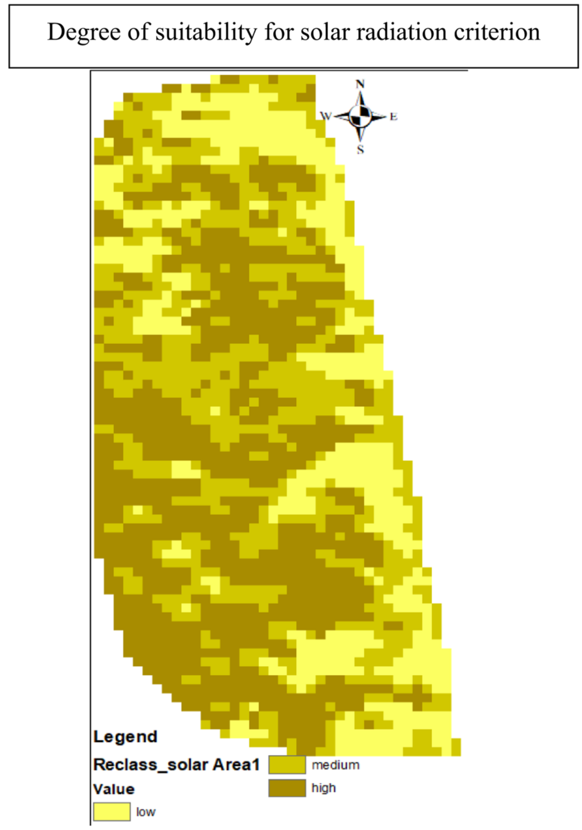

Fig. 19 Scores fit for solar radiation criterion (Source: The researcher)

The New Aswan city, as indicated by Fig. 7, is situated on the western bank of the River Nile, approximately 12 km away from the historic city of Aswan. It is projected to provide housing for a population of approximately 1 million individuals in the foreseeable future.

Selecting optimal locations for solar farms poses a significant difficulty. This dilemma posed a significant source of confusion for the electrical producing businesses. Due to the potential negative consequences, such as significant economic costs and the inefficient utilization of environmental resources (Charabi and Gastli 2010), an incorrect choice is very undesirable.

Spatial data analysis was used to determine the appropriate site for the solar farm (Brzezinska-Klusek et al. 2013). The primary sources of spatial data utilized for the material were the Urban Communities Authority for New Cities and the Urban Planning Authority.

The principal sources of data utilized in this study included a worldwide digital elevation model known as The Shuttle Radar Topography Mission (SRTM3) (It is mounted on a Space Shuttle and obtains Earth surface data by remote sensing technology utilizing a synthetic aperture radar) (Fig. 8), a collection of topographic maps and contemporary satellite imagery. Additionally, solar radiation data and a map illustrating the spatial distribution of power plants were obtained from the Atlas of Renewable Energy Sources.

Furthermore, the acquisition of spatial reference system data utilizing the C-band overlap method was employed to gather information pertaining to slope and terrain. The spatial reference system employed for the SRTM data is the World Geodetic System 1984 (WGS84).

Based on the analysis conducted using the SRTM 3 global digital elevation model, it has been determined that the topographical variations within New Aswan city span from 82 to 179 m (Fig. 9), with an average elevation of 134 m. Furthermore, the present investigation employed the ARC GIS 10.3 software tool to compute the slopes, resulting in the generation of a grid surface that represents the slope values within the study area. The findings indicate that the slope exhibited a range of values spanning from zero to 13.9 degrees, with a mean value of 2.7 degrees. The diagram presented (in Fig. 10).

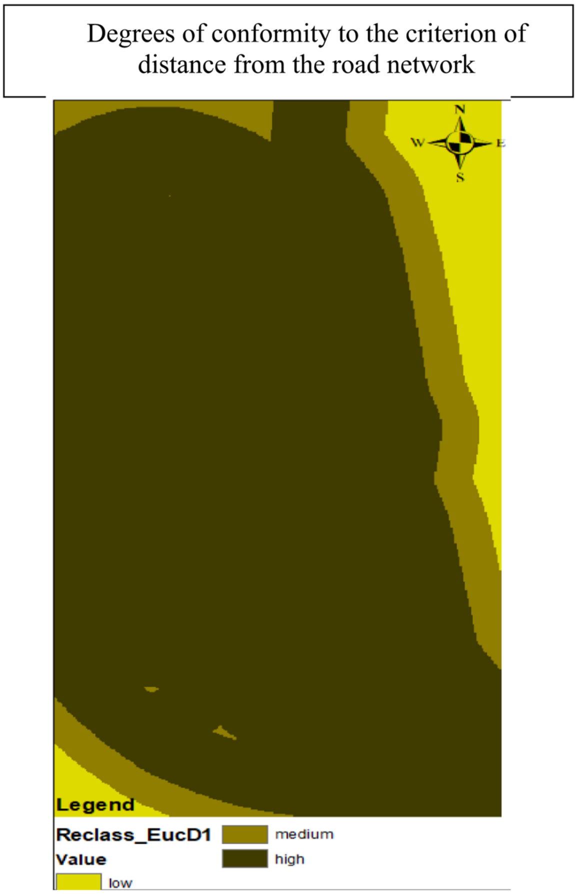

Fig. 20 Degrees of conformity to the criterion of distance from the road network (Source: The researcher)

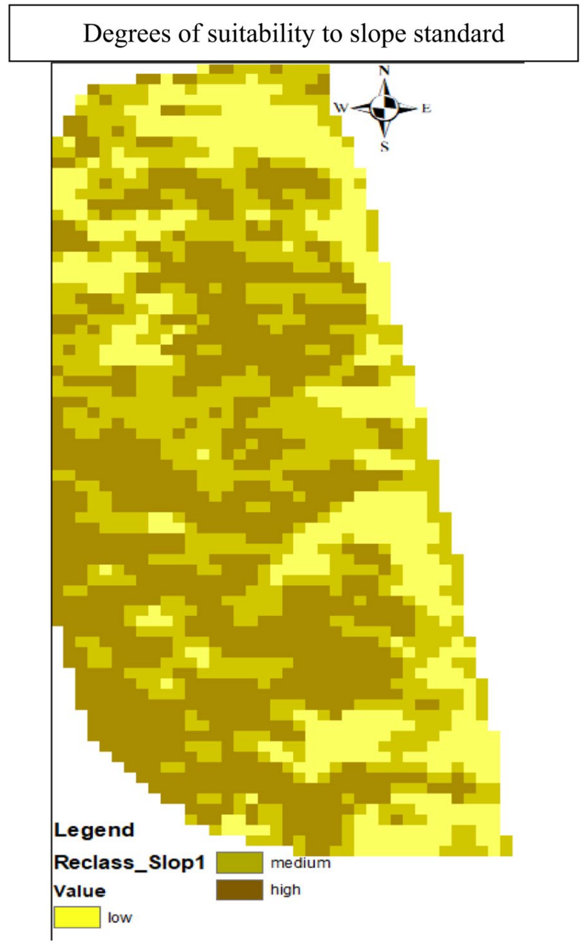

Fig. 21 Degrees of suitability to slope standard (Source: The researcher)

A map was generated using ARC G.I.S program application, incorporating crucial components such as land uses, the primary road network, and power stations, as they hold significant relevance in the decision-making process., (as shown in Fig. 11).

Through the examination of solar radiation data obtained from the Atlas of Renewable Energy Sources, it has been determined that the yearly mean solar radiation in New Aswan city varies from 1008.27 kwh/km^2 to 1147.689 kwh/km^2, with an average of 1091.650 kwh/km^2. According to (Fig. 12), it can be observed that the solar radiation exhibits a peak value at the central region of the city.

Data processing

The initial phase of data processing involved the establishment of a set of criteria that needed to be satisfied in order to identify the optimal spatial locations for solar energy collection initiatives. In this particular context, extensive global studies and substantial research pertaining to the subject matter were taken into account. As a result, a set of criteria was formulated to facilitate the identification and selection of optimal sites for the establishment of solar energy collection projects, with a focus on maximizing efficiency (Hassaan 2015; Recanatesi 2014; Aydin 2013).

The amount of solar radiation that arrives to the surface of the earth is the first standard for gathering solar energy, followed by considering the topology of the Earth's surface, which affects the tools and structure of machines needed for these projects.

Moreover, the proximity of power stations is a crucial determinant, as the increased distance results in a corresponding escalation of energy loss during the transfer process and a subsequent rise in the expenses associated with power transmission. The consideration of the proximity to urbanized areas and transportation infrastructure is an important aspect to be taken into account when determining optimal sites for solar energy projects, from an environmental perspective. Several environmental and economic criteria were

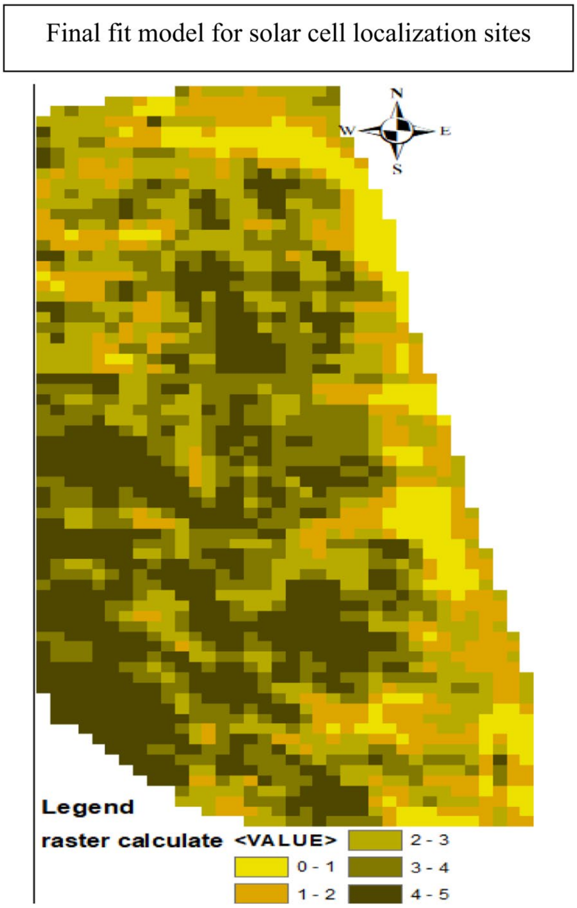

Fig. 22 Final fit model for solar cell localization sites (Source: The researcher)

selected, as indicated in Table 1, that must be met at the optimal location for a solar energy farm.

The final fit model was obtained by applying the stated weights (Equation No. 1) after reclassifying the approaches into degrees on a scale ranging from 1 to 5.

The respective weights of each of these criteria are indicated in the final column of the table. The data processing involved creating a network layer for each provided criterion, which categorized the criterion values into different categories (as shown in Fig. 13).

The evaluation of models was conducted by considering the categorization layers of assessment and analyzing the influence of these factors on the placement of solar cell farms.

The models were assessed using the classification layers of the criteria, which were created to consider the proximity to power stations, the main road network, solar radiation, topography, and inclinations Figs. 14, 15, 16, 17.

The results

The layers representing the values of each criterion were expanded to encompass the spatial extent that is deemed appropriate for each criterion individually. Results are shown through Figs. 18, 19, 20, 21.

Once the researcher integrated all the layers using the ARCG.I.S application, the intended outcome was achieved.

This outcome identifies the optimal location for solar farms, considering the previously described parameters. Choosing a site will be more efficient and cost-effective using this. This city is not suited for solar farms. The researcher utilized the Arc GIS tool to independently create maps and conduct analyses, ultimately arriving at these findings. The researcher who created the database and conducted the analyses is the source of these maps and analyses Fig. 22.

Preliminary models that are deemed suitable, such as the spatial suitability model, have been developed to assess the criterion of proximity to power stations. It has been observed that places at a maximum distance of 1.9 km from the power stations in this network are considered extremely suitable. The initial model proposed for assessing the proximity to important roads suggests that there are a greater number of spatial locations available as the city's road network increases extensively. The initial model for assessing the slopes of the Earth's surface indicates that a majority of the city's areas exhibit favorable levels of suitability.

The findings of the final fitted model reveal that specific locations exhibit varying degrees of priority for the establishment of solar cell farms.

These locations are categorized into four to five, representing the highest priority. The second priority is assigned to areas falling within the range of three to four, while the third priority is given to areas falling within the range of two to three. Furthermore, certain places demonstrate lower suitability and efficiency for the installation of solar farms, with values ranging from one to two.

For decision-makers, these results indicate the locations in New Aswan city that are most suitable and efficient for the installation of solar energy farms, aiming to generate electric power across the city through one of the most significant sources of renewable energy (the Sun).

Conclusion and recommendations

The findings of this study provide valuable insights for policymakers regarding the optimal and effective sites for implementing solar energy farms in New Aswan city. The objective is to harness solar power, a prominent renewable energy source, in order to create electricity across the city.

The research location was determined by analyzing a group of spatial databases, taking into consideration various economic and environmental variables. Subsequently, a digital suitability model was developed based on this analysis. Following an extensive spatial examination of New Aswan city, the findings obtained revealed that a significant proportion of the urban area is suitable for the implementation of solar farm initiatives, albeit with varying degrees of suitability. This study further suggests the application of the multi-criteria GIS technique to all energy-related development plans.

Author contributions
The corresponding author, D.R. Shery William Salama, wrote the paper, analysed, and performed both theoretical and analytical data.

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Availability of data and materials
The datasets used and/or analysed during the current paper are available from the corresponding author on reasonable request.

Declarations

Competing interests
The author declare that she has no competing interests.

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