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Evaluation Factors of Solar Power Plants to Reduce Cost Under Neutrosophic Multi-Criteria Decision Making Model

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Abstract: Solar power facilities must be efficient, reliable, and sustainable to meet energy demands. This study conducts a comprehensive analysis of criteria for evaluating solar power installations, focusing on factors impacting performance, economic viability, and environmental sustainability. Drawing from extensive literature, industry practices, and case studies, we identify key considerations such as technological feasibility, economic viability, environmental impact, legal frameworks, and social acceptance. To address the complexity and uncertainty associated with these criteria, we employ a multi-criteria decision-making approach. Specifically, the CRiteria Importance Through Inter-criteria Correlation (CRITIC) method is utilized to determine the weights of criteria, while the neutrosophic set theory is integrated to handle uncertain information during the evaluation process. The findings of this research offer valuable insights for academia, policymakers, and solar industry investors, facilitating informed decision-making in the pursuit of efficient and sustainable solar power solutions.

Keywords: Solar Power Pants, Multi-Criteria Decision Making, Neutrosophic Set, Energy, Sustainability.

1. Introduction

In an era characterized by an increasing global focus on sustainable energy solutions, solar power has emerged as a pivotal player in the quest for a clean and reliable energy future. Solar power installations have experienced rapid growth, driven by advancements in technology, favorable economic factors, and the imperative to mitigate environmental impact. However, ensuring the efficiency, reliability, and economic viability of these installations remains a multifaceted challenge [1]. The sustained operation and optimization of solar power facilities necessitate systematic evaluations that encompass a spectrum of factors, ranging from technological feasibility to environmental sustainability. These factors are not only interconnected but also influenced by an array of dynamic and uncertain variables. In this context, the assessment of solar power plants becomes a complex multi-dimensional problem, where traditional evaluation methods often fall short [2].

The urgent need to address climate change and decrease dependency on fossil fuels has prompted a considerable movement in recent years towards renewable sources of energy worldwide. While there are many renewable energy sources available, solar power has quickly risen to the forefront due to its ability to provide reliable, cost-effective, and environmentally friendly power. As solar power grows in popularity, it's more important than ever to set up and evaluate solar power plants to guarantee their efficiency, dependability, and long-term profitability [1], [2].

The performance, economic viability, and environmental sustainability of solar power plants are all taken into account throughout the evaluation process. Solar power plant strategy, design, and operation, as well as investment decisions, may all benefit greatly from a thorough understanding of these aspects [3], [4].

The purpose of this study is to provide criteria for assessing solar power projects. This research aims to determine what variables affect solar power plant efficiency, productivity, and success by reviewing relevant literature, industry practices, and case studies. The study's results will help shed light on the most important factors to think about when assessing and launching solar energy initiatives [5], [6]. Technical issues, economic viability, environmental effects, legal frameworks, and social acceptability are only some of the elements of assessment that are being explored. Solar panel efficiency and dependability, solar technology selection (photovoltaic or concentrated solar power), energy storage capacities, and grid integration are all examples of technical considerations. The levelized cost of electricity (LCOE), return on investment (ROI), and financial incentives or subsidies are all examples of elements used in economic assessment. The carbon footprint, water consumption, and land needs of solar power facilities are all examples of environmental concerns to consider. Critical evaluative elements also include regulatory frameworks such as regulations, standards, and permitting processes, as well as public support and participation [7], [8].

This study seeks to offer a complete overview of the evaluation criteria that play an important role in the development, assessment, and optimization of solar power plants by critically analyzing and synthesizing the current literature and case studies. Policymakers, investors, energy firms, and academics all have a stake in the design, construction, and maintenance of solar installations, thus the results will be of great use to them. Additionally, the highlighted gaps and problems in the current literature will guide future research paths and pave the way for additional breakthroughs in solar power plant assessment approaches [9], [10].

Consideration of technical, economic, environmental, regulatory, and social concerns is essential when assessing solar power facilities. This study intends to add to the current body of knowledge by giving a thorough examination of the criteria used to assess solar power projects.

The research results will help people make better choices, advance sustainable development, and encourage widespread use of solar power as an integral part of the global energy transition. This paper used the neutrosophic set to overcome the uncertain data in the evaluation. The neutrosophic set integrated with the CRITIC method to compute the weights of criteria.

It was Diakoulaki et al. who first implemented the CRITIC approach. When trying to solve MCDM issues, it is acceptable to use attribute weights. Contrast strength and uniqueness are also included in the weights [11], [12]. To get at all the data included in the valuation criteria, the CRITIC approach evaluated both the relative strength and the conflict of the criterion. Combining this approach with others makes it applicable to several fields [13], [14].

2. Background

To create electricity, large-scale solar power plants, often called solar farms or solar parks, collect sunlight. To harness the sun's rays for electricity production, these facilities often use photovoltaic (PV) panels or concentrated solar power (CSP) systems. To reduce greenhouse gas emissions and speed up the shift to renewable energy, solar power plants are crucial [15], [16]. Some essential features and parts of solar power plants are as follows:

Multiple solar panels or modules that house photovoltaic cells make up a solar power plant. Through the photovoltaic effect, these cells can convert sunlight into DC power. The frameworks on which solar panels are installed allow for them to be angled and tilted in such a way as to maximize their absorption of sunlight. A variety of mounting options are available, including stationary structures and tracking systems that move with the sun throughout the day [17], [18].

Inverters are used to convert the direct current (DC) power generated by solar panels into alternating current (AC). Powering homes, companies, and factories using AC energy is possible since it is grid compatible. Substations and transformers are used to efficiently transmit and distribute energy produced by solar power plants, respectively. Substations provide transmission of power from the plant to the grid and control of power distribution inside the plant [19], [20]. To keep tabs on the production, efficiency, and effectiveness of solar panels, solar power plants use monitoring and control systems. In addition to facilitating grid integration, power output control, and defect detection, these technologies also aid in the plant's overall management and optimization. Storage devices for extra electricity produced during peak sunshine hours are an optional component of several solar power projects. Batteries and other technologies may be utilized as part of energy storage systems, which then release their stored energy at times of high power demand or poor solar irradiation [21], [22].

Solar power plants are usually linked to the local power grid so that the energy they produce may be sent out to homes and businesses. Power that is produced in excess may be sold back to the grid via a grid connection, which generates cash and adds to the grid's total energy supply. Installation of solar panels and other necessary equipment for a solar power plant requires a large plot of land. Plant size considerations include capacity needs, access to solar resources, and zoning constraints.

When compared to power plants that rely on the combustion of fossil fuels, the environmental effect of solar power plants is minimal. They are environmentally friendly because they generate clean energy, reduce emissions of greenhouse gases, and consume less water in their operations. However, solar panels' production process and end-of-life disposal need to be managed properly to minimize their influence on the environment [23].To keep solar power plants running at peak efficiency and for as long as possible, routine maintenance is required. Panels must be cleaned, electrical connections must be inspected, and system performance must be monitored. Furthermore, problems or concerns must be repaired via regular inspections and maintenance. Solar power plants are important in the fight against climate change because they provide clean energy without using fossil fuels. Utility-scale solar farms, community solar installations, and distributed solar systems are all examples of their widespread use. As solar technology improves and prices drop, it becomes a more practical and appealing means of providing needed electricity in a sustainable and environmentally friendly way [24], [25].

3. Methodology

This section introduces the steps of the proposed method to compute the weights of factors. The neutrosophic set integrated with the CRITIC method to evaluate and rank the factors[26]–[29]. Figure 1 shows the conceptual framework of the proposed method. The following steps of the proposed method as:

Step 1. Design and set up the neutrosophic matrix.

For each decision maker and expert, the single-valued neutrosophic set is built.

$$R^{(k)} = [r_{ij}^{k}]_{m\times n} = \begin{bmatrix} r_{11}^{k} & \cdots & r_{1n}^{k} \\ \vdots & \ddots & \vdots \\ r_{m1}^{k} & \cdots & r_{mn}^{k} \end{bmatrix} \quad (1)$$

$$R = [r_{ij}]_{m\times n} = \begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{bmatrix} \quad (2)$$

$$r_{ij} = \left(1 - \prod_{k=1}^{l}\left(1 - T_{ij}^{k}\right)^{w_k}, \prod_{k=1}^{l}\left(I_{ij}^{k}\right)^{w_k}, \prod_{k=1}^{l}\left(F_{ij}^{k}\right)^{w_k}\right) \quad (3)$$

Where $k = 1,2,3, \dots . l\ (number\ of\ decision\ makers); i = 1,2,3 \dots m\ (alternatives), j = 1,2,3, \dots . n\ (criteria), \sum w_k = 1$

Step 2. Normalize the neutrosophic matrix.

The single-valued neutrosophic matrix is normalized based on cost and positive criteria.

$$NR = \begin{cases} (T_{ij}, I_{ij}, F_{ij})\ benefit\ criteria \\ (T_{ij}, I_{ij}, F_{ij})\ cost\ criteria \end{cases} \quad (4)$$

Step 3. Compute the correlation coefficient between factors.

$$CF = \frac{\sum_{i=1}^{m}\left((nr_{ij} - nr_j)(nr_{it} - nr_t)\right)}{\sqrt{\sum_{i=1}^{m}(nr_{ij} - nr_j)^2}\sqrt{\sum_{i=1}^{m}(nr_{it} - nr_t)^2}} \quad (5)$$

Where $j, t = 1,2,3, \dots . n$

Step 4. Compute the standard deviation of factors.

$$SDF = \sqrt{\frac{1}{m-1}\sum_{i=1}^{m}\left(\left(nr_{ij}\right) - \left(nr_j\right)\right)^2} \quad (6)$$

Step 5. Compute the factors' weights.

$$FW_j = \frac{SDF_j \ \sum_{t=1}^{n}\left(1 - CF_{jt}\right)}{\sum_{j=1}^{n}\left(SDF_j \sum_{t=1}^{n}\left(1 - CF_{jt}\right)\right)} \quad (7)$$

4. Experimental Results

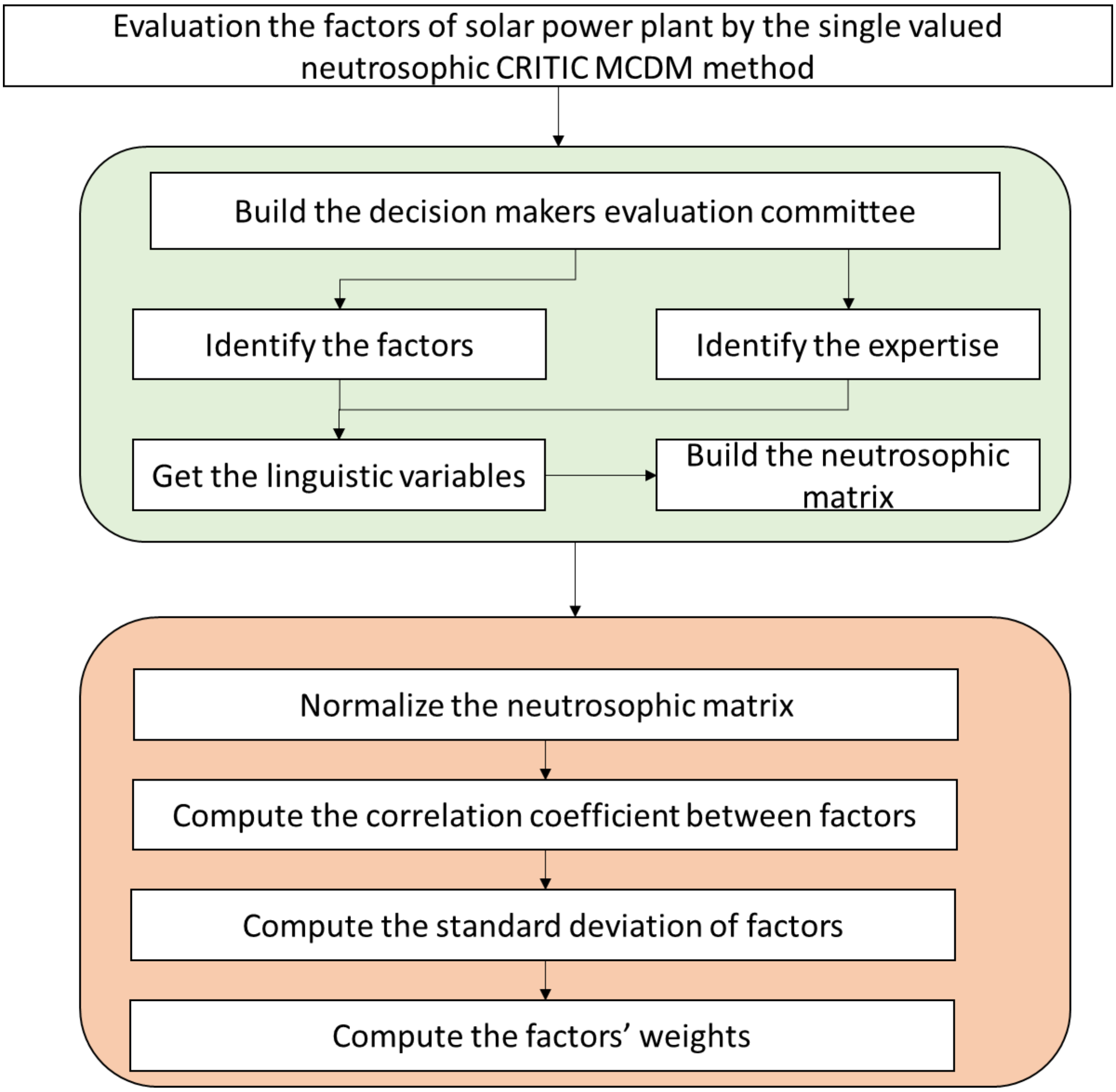

Figure 1. The framework of the single valued neutrosophic CRITIC method.

This section introduces the results of the proposed method to evaluate the factors of solar power plants. We used ten factors to be evaluated as follows:

Energy from the sun is used by solar power plants, sometimes called solar farms or solar photovoltaic (PV) power plants. There are a number of variables that affect how solar power plants are built, run, and ultimately function. Some crucial elements are as follows:

The performance of solar power plants is heavily influenced by the availability of solar resources, such as the intensity and length of sunshine. Solar power production is more effective in places that get greater solar irradiation and have more hours of sunlight each year.

Access to suitable land is also important when deciding where to build a solar power facility. Solar power plant viability and efficiency are affected by a number of factors, including proximity to the electrical grid, land availability, terrain, shading, and environmental issues (such as protected areas).

The effectiveness, cost, and overall performance of a solar power plant are all affected by the technology of the solar panels used. Efficiency, durability, and cost-effectiveness vary between solar panel types including monocrystalline, polycrystalline, and thin-film.

System Capacity and Design: The energy demand and available land area determine the capacity and design of a solar power plant. System performance is affected by variables such as the number of solar panels installed, their orientation, the power of the inverters, the effectiveness of the tracking systems (if any), and the quality of the interconnection infrastructure.

Overall energy conversion efficiency and electricity generation from a solar power plant are dependent on the efficiency and performance of the system as a whole, including solar panels, inverters, and balance-of-system equipment. Optimal system performance may be maintained by regular monitoring and servicing.

Integrating Solar Power Plants into the Grid Connecting solar power plants to the electrical grid and integrating them into the existing electricity infrastructure is essential. There are a number of factors that must be taken into account to ensure that power production and grid integration go off without a hitch, including but not limited to grid stability, voltage restrictions, power purchase agreements, and grid connection charges.

Financial Factors: The financial feasibility and return on investment of solar power plants are affected by factors such as the original capital investment, operating and maintenance expenses, financing choices, government incentives (such as tax credits, and feed-in tariffs), and electricity market dynamics.

The environmental effect of solar power plants is often lower than that of more traditional forms of electricity production. Land utilization, water use (in certain cooling systems), solar panel material, and component end-of-life management are all important considerations for ecologically responsible and sustainable operations. Permitting procedures, grid interconnection rules, net metering laws, and renewable energy objectives are all examples of regulatory and policy factors that may have a major impact on the construction and operation of solar power plants. Optimal performance and maximum energy output from solar power plants need diligent operation and routine maintenance. Scheduled cleaning and inspections, performance monitoring, problem detection, and preventive maintenance programs all contribute to the solar power plant's long-term viability. Taking these into account will allow those developing and operating solar power plants to maximize efficiency, save costs, and lessen their impact on the environment.

Step 1. In the first step, we build the single-valued neutrosophic matrix for all decision makers by using Eq. (1), then combine it by using Eqs. (2 and 3).

Step 2. Then normalize the single-valued neutrosophic matrix by using Eq. (4), all criteria are positive as shown in Table 1.

Table 1. The standardized single-valued neutrosophic matrix.

	RCF$_1$	**RCF$_2$**	**RCF$_3$**	**RCF$_4$**	**RCF$_5$**	**RCF$_6$**	**RCF$_7$**	**RCF$_8$**	**RCF$_9$**	**RCF$_{10}$**
RCP$_1$	0.317876	0	0.382924	0	0.577417	0.109245	1	0.396952	0.286489	0
RCP$_2$	0.522409	0.183107	0.381648	0.570671	0.3642	0.471374	0.841121	0	0.193234	0.006667
RCP$_3$	0.317876	0.549322	1	1	0.3642	0.481287	0.4919	0.181381	0	0.268333
RCP$_4$	0.693523	0.261995	0.158985	0.278975	0.24166	0.258952	0.82866	0.997254	0.058556	0.006667
RCP$_5$	0	0.027948	0.708127	0	0.810522	0	0	1	0	0.268333
RCP$_6$	0.145596	0.177876	0.382073	0.452297	0.24166	0.254097	0.479751	0.552108	0.410757	0.145
RCP$_7$	0.317876	0.399257	0.24025	0.560071	0	0.473397	0.88162	0.985995	0.27326	0.006667
RCP$_8$	0.81943	0.991533	0.958162	0.278975	0.819076	0.260773	0.88162	0.217081	0	1
RCP$_9$	1	1	0.666005	0.631272	1	1	0.178505	0.398188	0.27326	0.818333
RCP$_{10}$	0.94987	0.399257	0	0.051237	0.577417	0	0.002492	0.398188	1	0.541667

Step 3. Then compute the correlation coefficient of all factors by using Eq. (5) as shown in Table 2.

Table 2. The correlation coefficient of all factors.

	RCF$_1$	RCF$_2$	RCF$_3$	RCF$_4$	RCF$_5$	RCF$_6$	RCF$_7$	RCF$_8$	RCF$_9$	RCF$_{10}$
RCF$_1$	1	0.694286	-0.14286	0.017848	0.383543	0.360859	-0.08242	-0.33915	0.357058	0.631901
RCF$_2$	0.694286	1	0.479059	0.41805	0.44274	0.619231	-0.07811	-0.33525	-0.09335	0.848078
RCF$_3$	-0.14286	0.479059	1	0.403717	0.470568	0.28724	-0.03325	-0.34647	-0.68389	0.483258
RCF$_4$	0.017848	0.41805	0.403717	1	-0.29933	0.742655	0.122412	-0.34567	-0.30238	-0.00378
RCF$_5$	0.383543	0.44274	0.470568	-0.29933	1	0.112775	-0.47035	-0.26827	-0.05529	0.756634
RCF$_6$	0.360859	0.619231	0.28724	0.742655	0.112775	1	0.054769	-0.25209	-0.22485	0.246719
RCF$_7$	-0.08242	-0.07811	-0.03325	0.122412	-0.47035	0.054769	1	-0.12166	-0.38992	-0.36715
RCF$_8$	-0.33915	-0.33525	-0.34647	-0.34567	-0.26827	-0.25209	-0.12166	1	-0.10525	-0.33569
RCF$_9$	0.357058	-0.09335	-0.68389	-0.30238	-0.05529	-0.22485	-0.38992	-0.10525	1	0.065132
RCF$_{10}$	0.631901	0.848078	0.483258	-0.00378	0.756634	0.246719	-0.36715	-0.33569	0.065132	1

Step 4. Then compute the standard deviation of factors by using Eq. (6) as shown in Table 3.

Table 3. The standard deviation of factors.

	Standard Deviation
RCF$_1$	0.344282
RCF$_2$	0.356846
RCF$_3$	0.334113
RCF$_4$	0.32297
RCF$_5$	0.312798
RCF$_6$	0.297109
RCF$_7$	0.384808
RCF$_8$	0.364762

RCF_9	0.301501
RCF_{10}	0.363754

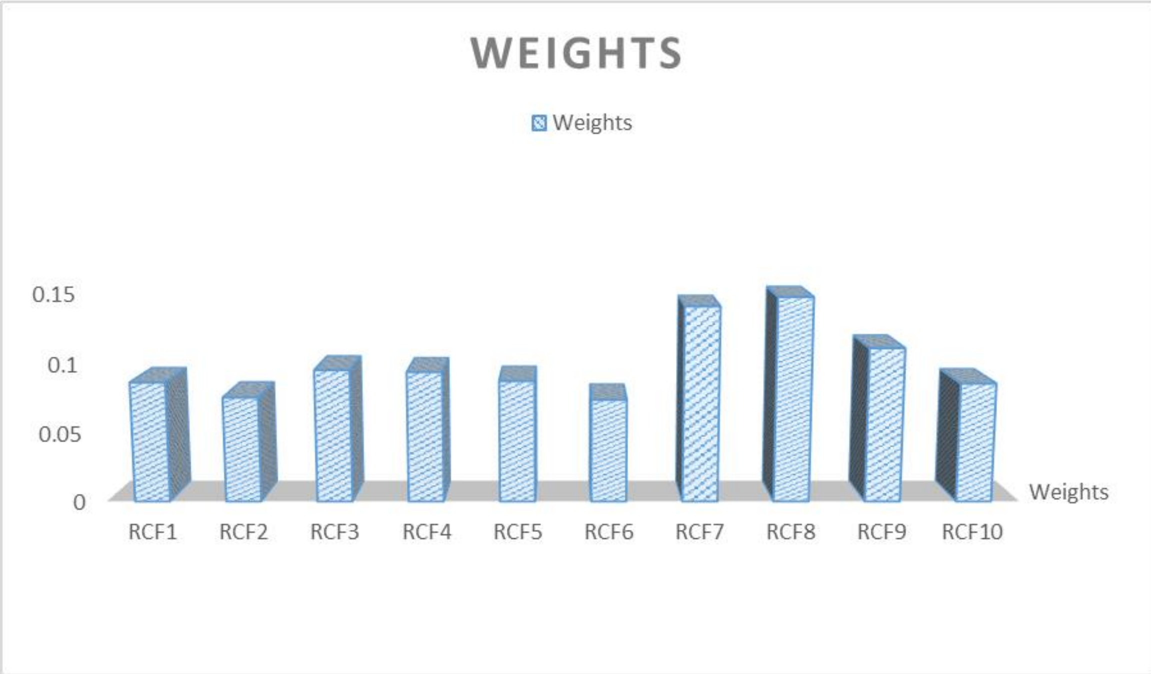

Figure 2. The weights of factors.

Step 5. Then compute the weights of factors by using Eq. (7) as shown in Figure 2. The financial factors are the highest weight.

5. Conclusions

To achieve a sustainable future, solar power plants are an essential part of the global energy shift. It is crucial to evaluate these plants for optimum performance and survivability. Key assessment parameters for solar power plants have been discovered and analyzed in this study using a thorough analysis of the relevant literature and case studies. Policymakers, investors, and academics may make better judgments on solar power plant development, implementation, and operation if they have a thorough grasp of these assessment elements. It makes it easier to see what can go well and what may go wrong so that better plans can be made. Further, the recommendations for future study and development in this subject are provided by the highlighted gaps and obstacles in the current literature on solar power plant appraisal. Evaluation of solar power plants is becoming more important as the globe transitions to renewable energy sources. This study adds to the literature by compiling and analyzing the assessment criteria for solar power facilities. It promotes sustainable development and aids the worldwide transition to a clean and renewable energy future while serving as a significant resource for anyone working in solar energy. This study used the neutrosophic set to deal with the uncertain data with the MCDM CRITIC method to compute the weights of factors. This study used ten factors to be evaluated. The results show the financial factor is the highest.

Supplementary Materials

Not applicable.

Author Contributions

For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, M.A. and M.J.; methodology, M.A.; software, M.A.; validation, M.A., and M.J.; formal analysis, M.A.; investigation, M.A.; resources, M.A.; data curation, M.J.; writing—original draft preparation, M.J.; writing—review and editing, M.A.; visualization, M.A.; supervision, M.A.; project administration, M.A. All authors have read and agreed to the published version of the manuscript.

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Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

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