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ANALYSIS TO DETERMINE THE MOST SUITABLE LOCATION FOR A PHOTOVOLTAIC SOLAR PLANT IN THE STATE OF RIO DE JANEIRO, BRAZIL

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ABSTRACT

Photovoltaic energy has becoming a viable and non-polluting alternative for generating electricity. In the light of this fact, this study aims to find the most suitable locations for a photovoltaic solar plant in the State of Rio de Janeiro, Brazil, considering environmental, technical and economic criteria. The fuzzy logic, with its membership functions, was used to compute the criteria that were applied in the GIS (Geographic Information System). The review of articles using the AHP (Analytic Hierarchy Process) provided the degree of importance for each selected criteria. The availability of each of the criteria combined with their relative importance generated a map of the most suitable regions for the location of the photovoltaic solar plant. The results show that the state of Rio de Janeiro has a great potential for photovoltaic solar energy generation, especially in the north coast, near the city of Campos dos Goytacazes, with the lowest potential in the mountainous region, due to the reduced amount of sunshine and greater slope.

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INTRODUCTION

Singh (2002) states that energy is a primary factor for the development and improvement of the quality of life of the societies and, according to Goldemberg (2003), the increase in demand and consumption of electricity is caused by technological progress and the development of humanity. Consequently, obtaining this resource in a sustainable and competitive manner is crucial (TSOUTSOS *et. al.* 2005). According to Pereira *et al.* (2006), the increase of energy demand, the reduced supply of conventional fuels and the growing environmental concerns are incentives to research and develop alternatives less pollutant and renewable as energy sources. The World Bank (2019), through a report available on its website, states that CO_2 from electricity generation, is a major contributor to climate change, including in Brazil. Solar energy stands out in this scenario as a solution because it can be found anywhere and makes up 99.8% of all energy that reaches the surface of the Earth, making it an accessible and inexhaustible energy source (RAMEDANIR *et al.*, 2013 and AL -SHAMISI *et al.*, 2013). According to IRENA (International Rewable Energy Agency), photovoltaic solar energy is becoming increasingly competitive due to its cost reduction (IRENA, 2018).

As a matter of fact, the costs of photovoltaic systems have fallen more than 100 times since 1950, and between 1980 and 2013 there was a reduction of approximately 21.5% (NEMET, 2006 and EPE 2018 - B). Investment costs in photovoltaic systems are expected to decrease by 30% between 2020 and 2050 (EPE 2018 - B) and, according to IRENA (2018), large photovoltaic plants are expected to generate electricity by 2020 at a cost of approximately $ 0.06 per kwh, competing with traditional power sources. According to the IBGE (Brazilian Institute of Geography and Statistics), Rio de Janeiro has an area of 43,752.8 km² and tts population is, 17.2 million people (IBGE, 2019). Regarding its economy, the FIRJAN (Federation of Industries of the State of Rio de Janeiro) states that GDP per capita is 25% higher than the Brazilian average (FIRJAN, 2018).

MATERIALS AND METHODS

To determine the most suitable location of a photovoltaic solar plant in the state of Rio de Janeiro, the following steps will be followed:

- Review academic papers for the selection of localization criteria to be analyzed;

- Allocate weight to localization criteria through articles using the AHP method;
- Determine the restriction zones, places where the solar plant cannot be located;
- Use fuzzy logic to determine the membership functions of the selected localization criteria;
- Generate in the GIS a final layer weighting of all factors, thus showing the most suitable regions for the plant.

Selection and Weight of the Criteria

The choice of the criteria to locate the photovoltaic plant was defined based of the reviewed articles. If the criteria appear in more than 40% of the analyzed articles it will be considered as a valid one, the other ones were considered local peculiarities. So, the following were the chosen location factors with its degree if importance were:

Solar Irradiation (42.42%): The World Bank (2011) states that high rates of solar irradiation is the most basic factor for developing a photovoltaic solar plant project in any region, this affirmation is corroborated by Lubitz (2011).

Average temperature (11.34%): energy generation by the solar panels is reduced with the increase of its operating temperature it means that the panels are less efficient as higher its operating temperature (SIMIONI, 2017).

Distance to Transmission Lines (9.12%): Azevêdo (2016) states that the requirements for connecting the solar plant to the grid are similar to those of other thermoelectric plants. Therefore, is crucial to use transmission lines with sufficient capacity as close as possible to the solar plant, as the costs of building new transmission lines are usually high and correlated to its length.

Distance to Transport Links (5.33%): accessibility is a relevant factor, particularly due to the need to transport equipment. Thus, the proximity of transportation infrastructure to the site of the plant is a relevant requirement and may have consequences on the overall cost of operation and construction (AZEVÊDO, 2016).

Distance to Urban Centers (5.68%): EPE (2018-A) states that distributed power generation can be located closer to urban centers, that is, near the places that require the most electricity, which has the benefit of reducing electrical losses.

Slope (13.69%): the panels should preferably be located in flat areas. According to the World Bank (2011), n addition the flat terrain still significantly reduces installation and maintenance costs.

Azimuth (8.50%): the World Bank (2011) states that, in the Southern Hemisphere, the panels should be facing north to receive as much solar radiation as possible.

Land Use (3.92%): most of the articles considered that the criteria "land use" is equivalent to soil fertility. That is, the more fertile the soil is less recommended is to the plant.

All articles considered restriction zones, that is, regions where the photovoltaic solar plant could not be located, either for legal reasons or for a physical restriction. Based on those, the following ewre considered restriction zones: Protected areas, forests, indigenous territories, quilombola territories, urban areas and water bodies (rivers, lakes, etc).

RESULTS

Applying the Selected Criteria: Fuzzy logic and membership functions were used to create all layers representing each location criteria to be used in GIS. Each layer has a value between zero and one. The higher the value, the greater the suitability for the installation of the photovoltaic solar plant. And using the weights of each criteria, based on previous studies, generates the final layer that has the most suitable for the photovoltaic solar plant. The definition of fuzzy membership functions were developed from the location factors chosen through the analysis of the reviewed articles.

Solar Irradiation

$\mu(X) = \frac{X}{5200}$, x = solar irradiation

Temperature: $\mu(X) = 1-0.334X$, X = temperatures above 9ºC.

Distance to Transmission Lines

$\mu(X) = 1$ for $0<X<5$km
$\mu(X) = 0.75$ for $5<X<10$km
$\mu(X) = 0.5$ for $10<X<15$km
$\mu(X) = 0.25$ for $15<X<20$km
$\mu(X) = 0$ for $X>20$Km, X = Distance to transmission lines (km)

Distance to Transport Links

$\mu(X) = 1$ for $0<X<2.5$km
$\mu(X) = 0.8$ for $2.5<X<5$km
$\mu(X) = 0.6$ for $5<X<7.5$km
$\mu(X) = 0.4$ for $7.5<X<10$km
$\mu(X) = 0.2$ for $10<X<12.5$Km
$\mu(X) = 0$ for $X>12.5$Km

Distance to Urban Centers

$\mu(X) = 1$ for $0<X<5$km
$\mu(X) = 0.66$ for $5<X<10$km
$\mu(X) = 0.33$ for $10<X<15$km
$\mu(X) = 0$ for $X>15$Km

Slope

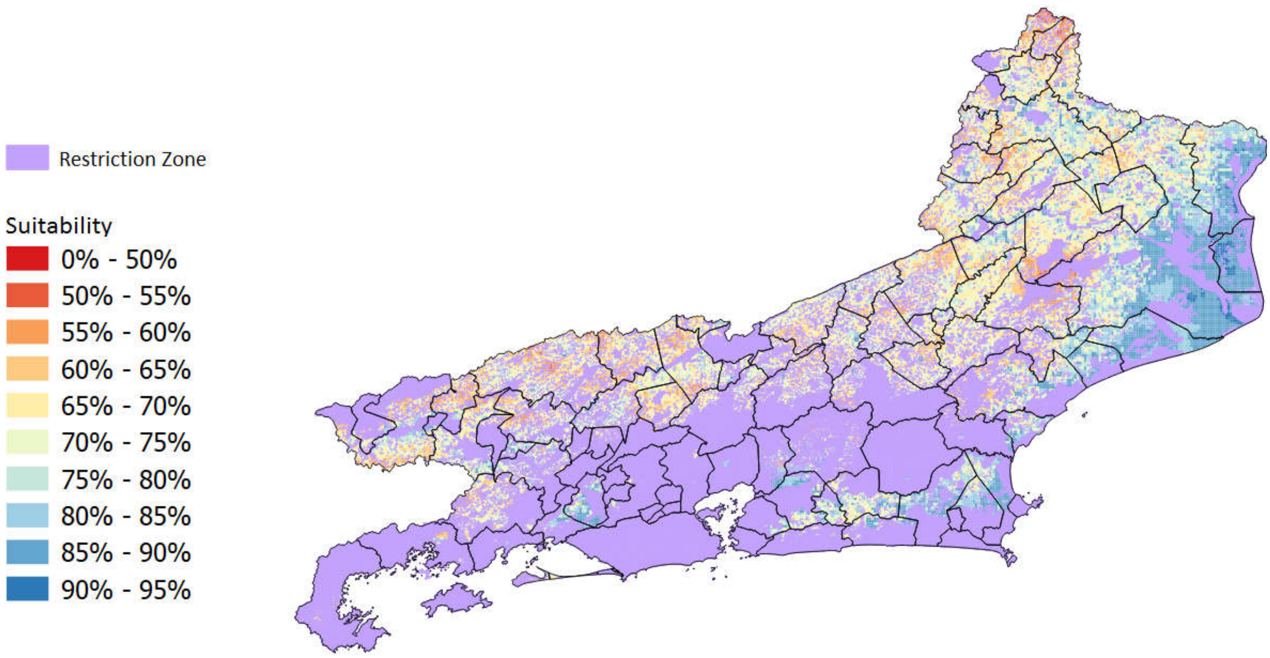
$\mu(X) = 10-X$, X is the percentage of inclination. If $x>10$, $\mu(X)=0$

Azimuth

If inclination< 2%, $\mu(X) = 1$
Azimuth = North, $\mu(X) = 1$
Azimuth = Northeast, $\mu(X) = 0.7$
Azimuth = Northwest, $\mu(X) = 0.7$
Azimuth = Est, $\mu(X) = 0.5$
Azimuth = West, $\mu(X) = 0.5$
Azimuth = Southeast, $\mu(X) = 0.3$
Azimuth = Southwest, $\mu(X) = 0.3$
Azimuth = South, $\mu(X) = 0$

Land Use

Fertility = Very Low, μ =1
Fertility = Low, μ =0,66
Fertility = Medium to High μ =0,33
Fertility = High, μ =0



Source: The Authors

Figure 1. Final Results

The eight location criteria selected were compared according to their relative importance, estimated by reviewing the articles using the AHP Method, and the level of suitability were obtained by the fuzzy membership functions to generate the map of most suitable locations for thesolar photovoltaic power plant (figure 3). Looking at Figure 3, the region most suitable for receiving large-scale photovoltaic solar energy projects is the municipality of Campos dos Goytacazes and surroundings (Northwest) with suitabilities greater than 90%. Other very favorable regions are an area close to the metropolitan region of the city of Rio de Janeiro and another within the Região dos Lagos, both with greater than 80% aptitude. The mountainous region of the state had the lowest indexes for the solar photovoltaic plant's suitability. Another factor that drew attention was the extension of the restriction zone, which occupies a considerable part of the state, mainly because of the protection zones and urban areas.

DISCUSSION

In this study, the suitable location for a photovoltaic solar plant were defined using the combination of AHP method, GIS and fuzzy logic. Eight location criteria (ranging from environmental to infrastructural factors) with greater importance for solar irradiation were analyzed. The results showed that Rio de Janeiro, despite having a large region where it is not possible to install the solar photovoltaic plant, due to environmental restrictions (protection areas) and urban areas, has a good potential for the installation of solar photovoltaic plants, especially in the northern region. It should be noted that this study depended on the availability and quality of data, especially georeferenced data, which may yield slightly different results when updated.

REFERENCES

AL-SHAMISI MH; ASSI, AH; HEJASE, HAN. Artificial Neural Networks for Predicting Global Solar Radiation in Al Ain City – UAE. Int. J. Green Energy; 10:443–56. 2013.https://doi.org/10.1080/15435075.2011.641187.

AZEVÊDO, V W B. Estudo de Localização de Usina Solar Termoelétrica no Estado De Pernambuco. Dissertação de Doutorado. UFPE. Programa de Pós-Graduação em Tecnologias Energéticas e Nucleares. 2016. https://repositorio.ufpe.br/bitstream/123456789/17712/1/TESE%20N%20127%20-%20PROTEN%20DEN%20UFPE%20-%20VERONICA%20AZEVEDO.pdf

EPE (EMPRESA DE PLANEJAMENTO ENERGÉTICO). Premissas e Custos da Oferta de Energia Elétrica. 2018 – A.

EPE (EMPRESA DE PLANEJAMENTO ENERGÉTICO). Premissas e Custos da Oferta de Energia Elétrica no Horizonte 2050. 2018 – B.

FIRJAN (FEDERAÇÃO DAS INDÚSTRIAS DO ESTADO DO RIO DE JANEIRO). Retratos Regionais: Perfil Econômico Regional.2018.

GOLDEMBERG, J.; VILLANUEVA, L. D. Energia, Meio Ambiente r Desenvolvimento. São Paulo: EDUSP. 2003.

IBGE (INSTITO BRASILEIRO DE GEOGRAFÍA E ESTATÍSTICA) Disponível em Link: https://www.ibge.gov.br/apps/populacao/projecao/.

INTERNATIONAL FINANCE CORPORATION (WORLD BANK). Utility-Scale Solar Photovoltaic Power Plants. 2011.

IRENA (INTERNATIONAL RENEWABLE ENERGY AGENCY). Renewable Power Generation Costs in 2017. 2018.

NEMET, G. F. Beyond the learning curve: factors influencing cost reductions in photovoltaics. Energy Policy, v. 34, p. 3218-3232, 2006. https://www.sciencedirect.com/science/article/pii/S0301421505001795

PEREIRA, Enio Bueno. MARTINS, Fernando Ramos. Abreu, Samuel Luna. Ruther, Ricardo. Atlas Brasileiro de Energia Solar. 1ª Edição. 2006. INPE.

RAMEDANIR, Z;OMIDO, M, KEYHANI, A. Modeling solar energy potential in Tehran province using artificial neural networks. Int J Green Energy 2013; 10:427–41. https://www.researchgate.net/publication/236345200_Modeling_Solar_Energy_Potential_in_a_Tehran_Province_Using_Artificial_Neural_Networks

SIMIONI, Tássio. O Impacto da Temperatura para o Aproveitamento do Potencial Solar Fotovoltaico do Brasil. COPPE-UFRJ. Masters Degree Dissertation. 2017. http://www.ppe.ufrj.br/images/publica%C3%A7%C3%B5es/mestrado/T%C3%A1ssio_Simioni.pdf

SINGH, J.M., 2002. On Farm Energy Use Pattern in Different Cropping Systems in Haryana, India (MS. Thesis). International Institute of Management, University of Flensburg.

TSOUTSOS, T.; FRANTZESKAKI, N.; GEKAS, V. Environmental impacts from the solar energy technologies. Energy Policy, Volume 33, Issue 3, February 2005, Pages 289-296. https://www.sciencedirect.com/science/article/pii/S0301421503002416

World Bank, 2019– https://data.worldbank.org/indicator/en.co2.etot.zs?end=2014&start=1960&view=chart.

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