ZONING OF DEGRADED AREAS SUITABLE FOR IMPLEMENTATION OF RENEWABLE ENERGY GENERATION SYSTEMS: SYSTEMATIC REVIEW

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ABSTRACT

Objective: The objective of this study is to investigate and carry out a systematic review of the literature, with the aim of delving deeper into the topic of zoning and selection of areas for the implementation of renewable energy generating plants.

Theoretical Framework: In this topic, the main concepts and theories that underpin the research are presented. The elaboration of the research protocol in four stages: elaboration of questions, choice of databases, definition of the search strategy and inclusion/exclusion criteria, providing a solid basis for understanding the context of the investigation.

Method: The methodology adopted for this research comprises the choice of databases and definition of the search string based on the research protocol. Data collection was made by searching Scopus, Science Direct, Web of Science and Energy Citations Database (OSTI).

Results and Discussion: The results obtained revealed that 309 studies met the research protocol, of which only 29 studies, after reading the abstract, were ready for the full article reading stage. Seven of these were accepted as relevant to the objective, being classified as accepted and participating in the information gathering to meet the proposed objective.

Research Implications: The practical and theoretical implications of this research are discussed, providing insights into how the results can be applied or influence practices in the field of georeferencing. These implications may include public and private enterprises that aim for a less environmentally aggressive methodology for selecting sites for renewable energy generation.

Originality/Value: This study contributes to the literature by showing the most relevant points and the main gaps in current selection methodologies. The relevance and value of this research are highlighted by representing a new way of thinking about choosing new locations for power plants.

Keywords: Power Plants, Remote Sensing, Georeferencing, Solar Energy, Wind Power.

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ZONEAMENTO DE ÁREAS COM PASTAGENS DEGRADADAS APTAS A IMPLEMENTAÇÃO DE SISTEMAS DE GERAÇÃO DE ENERGIA RENOVÁVEL: REVISÃO SISTEMÁTICA DA LITERATURA

RESUMO

Objetivo: O objetivo deste estudo é efetuar uma revisão sistemática da literatura, com o intuito de aprofundar sobre o tema do zoneamento e seleção de áreas para implementação de usinas geradoras de energia renovável.

Referencial Teórico: Neste tópico, são apresentados os principais conceitos e teorias que fundamentam a pesquisa. Destaca-se a elaboração do protocolo de pesquisa em quatro etapas: elaboração das questões, escolha das bases de dados, definição da estratégia de busca e dos critérios de inclusão e exclusão, fornecendo uma base sólida para a compreensão do contexto da investigação.

Método: A metodologia adotada para esta pesquisa compreende a escolha das bases de dados e definição da string de busca com base no protocolo de pesquisa. A coleta de dados foi realizada por meio da busca em Scopus, Science Direct, Web of Science e Energy Citations Database (OSTI).

Resultados e Discussão: Os resultados obtidos revelaram que 309 estudos atenderam ao protocolo de pesquisa, sendo que destes apenas 29 estudos, após leitura do resumo, estavam aptos para etapa da leitura integral do artigo. Sete destes foram aceitos como relevantes ao objetivo, sendo classificados como aceitos e participando do levantamento de informações para atender ao objetivo proposto.

Implicações da Pesquisa: As implicações práticas e teóricas desta pesquisa são discutidas, fornecendo insights sobre como os resultados podem ser aplicados ou influenciar práticas no campo de georreferenciamento. Essas implicações podem abranger órgãos públicos e privados que visem uma metodologia menos agressiva ambientalmente para seleção de locais para geração de energia renovável.

Originalidade/Valor: Este estudo contribui para a literatura ao mostrar quais os pontos mais relevantes e as principais lacunas nas metodologias de seleção atuais. A relevância e o valor desta pesquisa são evidenciados por representarem uma nova forma de se pensar a escolha de novas localidades para usinas energéticas.

Palavras-chave: Usinas, Sensoriamento Remoto, Georreferenciamento, Energia Solar, Energia Eólica.

ZONIFICACIÓN DE LAS ZONAS DEGRADADAS ADECUADAS PARA LA APLICACIÓN DE SISTEMAS DE GENERACIÓN DE ENERGÍA RENOVABLE: REVISIÓN SISTEMÁTICA

RESUMEN

Objetivo: El objetivo de este estudio es investigar y realizar una revisión sistemática de la literatura, con el objetivo de profundizar en el tema de zonificación y selección de áreas para la implementación de plantas generadoras de energía renovable.

Marco Teórico: En este tema se presentan los principales conceptos y teorías que sustentan la investigación. La elaboración del protocolo de investigación en cuatro etapas: elaboración de preguntas, elección de bases de datos, definición de la estrategia de búsqueda y criterios de inclusión/exclusión, proporcionando una base sólida para comprender el contexto de la investigación.

Método: La metodología adoptada para esta investigación comprende la elección de bases de datos y la definición de la cadena de búsqueda basada en el protocolo de investigación. La recopilación de datos se realizó mediante la búsqueda en Scopus, Science Direct, Web of Science y Energy Citations Database (OSTI).

Resultados y Discusión: Los resultados obtenidos revelaron que 309 estudios cumplieron con el protocolo de investigación, de los cuales solo 29 estudios, después de leer el resumen, estaban listos para la etapa de lectura completa del artículo. Siete de ellos se aceptaron como pertinentes para el objetivo, se clasificaron como aceptados y participaron en la recopilación de información para cumplir el objetivo propuesto.

Implicaciones de la Investigación: Se discuten las implicaciones prácticas y teóricas de esta investigación, proporcionando información sobre cómo se pueden aplicar los resultados o influir en las prácticas en el campo de

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la georreferenciación. Estas implicaciones pueden incluir empresas públicas y privadas que buscan una metodología menos agresiva para seleccionar sitios para la generación de energía renovable.

Originalidad/Valor: Este estudio contribuye a la literatura al mostrar los puntos más relevantes y las principales lagunas en las metodologías de selección actuales. La relevancia y el valor de esta investigación se destacan al representar una nueva forma de pensar sobre la elección de nuevas ubicaciones para las centrales eléctricas.

Palabras clave: Centrales eléctricas, Teledetección, Georeferenciación, Energía Solar, Energía Eólica.

1 INTRODUCTION

Remote sensing and geoprocessing, whose techniques are intended to detect and characterize the Earth's surface from a distance (PÉREZ MARTÍN et al., 2020) and to treat this data with a specific objective (REGHINI & CAVICHIOLI, 2020) are important and growing practices in the environmental area (GUEDES, 2018).

Given the huge variety of themes that can be researched using satellite imaging, we have land use as one of the main ones (INÁCIO, BARBOZA & BRUNO, 2020). As an important subdivision of land occupation, the analysis of degraded regions without social, political and economic use is an extremely relevant point. Degraded areas are those that are unable to return to their natural state without intervention and that, even with interventionist practices, are unlikely to be recovered, only restored (BRASIL, 2014).

In this way, they can be directed to new uses, such as energy generation. This is a very important topic, given that national demand has been growing rapidly – potentially tripling by 2050 (SANTOS, 2018). Satellite images can be used in zoning locations for sustainable energy sources (REGINATO, 2020). Zoning is a mandatory instrument of the National Environmental Policy that aims to ensure environmental quality.

The generation of clean energy involves not only the choice of appropriate electricity generation techniques, but also the planned choice of a location for the implementation of a "green plant". Therefore, the use of remote sensing and geoprocessing techniques is very relevant in the process of proposing new areas for generating electrical energy.

In this way, this study aims to carry out a strategic and guided process aiming to learn more in depth about zoning and selection of areas for the implementation of renewable energy generating plants. This was carried out through a systematic literature review (RSL) in order to

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bring together studies of a similar nature and synthesize knowledge about a topic, according to its objective according to Ramos, Durante & Callejas (2017).

2 THEORETICAL FRAMEWORK

The systematic review must be conducted in a pre-determined, clear and reproducible manner, with very well defined parameters such as keywords, inclusion and exclusion criteria. This planning constitutes the so-called "Research Protocol", which is basically the survey of what you want to answer and the method for doing so (DERMEVAL, COELHO & BITTENCOURT, 2020).

The elaboration of the protocol passes, according to Qazi et al. (2019) through four stages: elaboration of the questions to be answered; choice of research strategy – databases; definition of the search strategy; and selection of inclusion and exclusion criteria. Based on these procedures, the bibliography related to the research topic was surveyed.

3 METHODOLOGY

The guiding questions were: 1) Are there articles that discuss the opening of new energy generating units, using renewable typologies, in georeferenced degraded areas?; 2) If yes, what typologies are addressed by the authors and; 3) What parameters are used by the authors to determine the suitability of an area for the possibility of opening a new renewable energy generation point.

The choice of databases was made from the collection options available on the CAPES Periodicals Portal. Bases with recognition supported by academia and which have publications in the areas of geographic, environmental and agricultural sciences were chosen. Therefore, the following databases were used: Scopus , Science Direct , Web of Science and Energy Citations Database (OSTI). The information was collected in January/2024, with no limitation on the date of production of the work. The strategies are described in Table 1.

Table 1

Search strategies for each database used

Base	Database search strategy
Scopus	TITLE-ABS-KEY ((renewable AND energy) AND (land OR lands OR area OR areas) AND (reuse OR rehabilitation OR restoration) AND (contaminated OR degraded OR use)) AND (LIMIT-TO (DOCTYPE , "ar")).

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Science Direct	(renewable energy) AND (land OR area) AND (reuse OR rehabilitation OR restoration) AND (contaminated OR degraded OR use); Busca na aba "Title, abstract, keywords:" e aplicando filtro "Research articles".
Web of Science	(renewable energy) AND (land OR lands OR area OR areas) AND (reuse OR rehabilitation OR restoration) AND (contaminated OR degraded OR use); Busca na aba "Topic (Title, abstract, keywords)" e aplicando filtro: "Article".
Energy Citations Database	(renewable energy) AND (land OR lands OR area OR areas) AND (reuse OR rehabilitation OR restoration) AND (contaminated OR degraded OR use); Aplicando filtro "Journal Article".

The strategy presented in Table 1 was thus constructed in order to seek any and all references to degraded areas that could obtain a new socioeconomic utility through the production of sustainable energy. Filters or addenda were applied to formulas that returned only primary articles. Search strategies differ in structure due to database standards, aiming for the same return as databases.

For the articles returned through the presented strategy to be accepted for full reading, it would be enough for their title and summary to indicate the possibility of answering at least one of the aforementioned guiding questions. In the full text reading stage, for the article to be accepted it must answer, even preliminarily, the three questions.

4 RESULTS AND DISCUSSIONS

The inclusion criteria look for primary articles that have a title, abstract and keywords aligned with the research protocol. Those excluded are duplicate and redundant articles by the same author – something that recurs in searches on different bases – and those not written in English and Portuguese, due to the difficulty in correctly interpreting the text beyond these languages.

To help control information, upload downloaded data to databases and include/exclude in an organized manner, the online software Rayyan was used . Based on the strategy presented, all records that met the described criteria were collected. Afterwards, duplicates and redundant items were removed, resulting in an eligible group. In this group, the abstracts were evaluated, excluding those that did not deal with a topic capable of answering the questions raised. Figure 1 presents the results flowchart.

There was a significant reduction – around 90% – from the total number of works (309) to the amount that had their title and summary in accordance with the purpose of the review (29). This is due to the fact that many articles addressed the issue of land use and occupation with degradation, citing the infinite possibilities for reuse – including energy generation – but did not discuss any process or typology of energy generation processes, focusing on in other

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areas of knowledge such as, for example, bioremediation, public policies, changes in the landscape and hydrological cycles.

After this step, the group of included articles was obtained. This brings articles that in some way, based on their summary, address one or more questions in line with this research. Within this group, the articles were downloaded onto their respective platforms and analyzed in full. It is worth noting that only one of the 29 articles did not present its full text via the CAPES platform. However, direct contact was made via email with Christopher De Sousa, one of the authors of the work Spiess & De Sousa (2016), who promptly made himself available to send. Figure 1 presents the results flowchart.

Reading the texts of the articles in full resulted in seven studies capable of answering all the questions raised. The remaining 21 articles, although excluded, were still analyzed since, even though they did not meet the criteria, they contained very important information capable of enriching the present work.

Table 2 presents the excluded articles, reason for exclusion and information collected that may contribute to knowledge and/or validation of the research.

Figure 1

Process flowchart and results by stages

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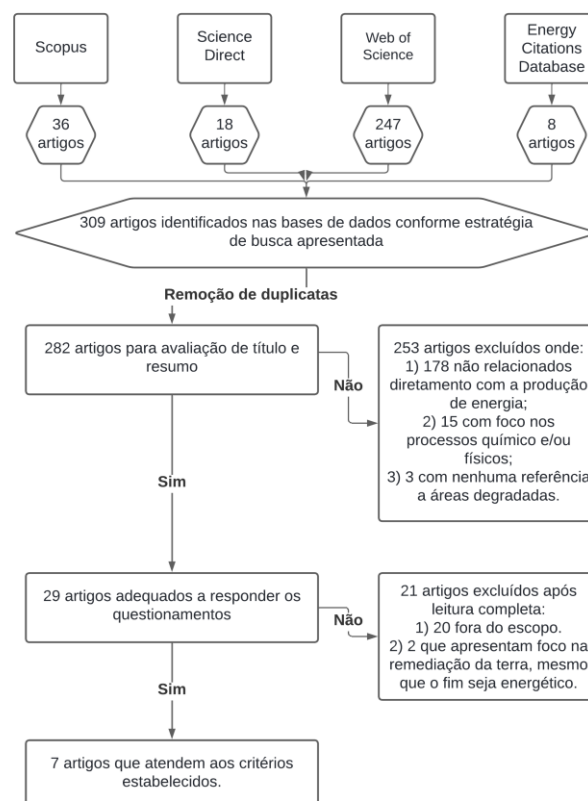
Table 2

Articles read in full and excluded for not answering the guiding questions.

Reference	Reason for exclusion	Information relevant
Gómez et al. (2023).	Research focus on evaluating the land's treatment capacity through biomass growth - Phytoremediation . There was no selection of areas using georeferenced data.	The work concludes that the presence of potentially toxic elements in the soil and – subsequently – in the biomass of plants that grew in contaminated soil can negatively affect their combustible utility.
Moustafa et al. (2022).	The main analysis is on the associated costs and not on the search for areas with geothermal potential. There was no selection of areas using georeferenced data.	The work concludes, based on simulations in existing abandoned wells, that the use of geothermal energy in places where wells are already installed reduces costs by 40% to 60%.
Liu et al. (2011).	The work carried out a SWOT analysis on the use of degraded land in biomass production. No there was none type of georeferenced data .	It is concluded that biomass planting is a great possibility for generating jobs and positive environmental impacts, although there are financial reservations.
Ott et al. (2021).	The study aims to provide a comprehensive review of energy generation in plains and does not use any aspect of georeferenced data processing.	It was concluded that despite many benefits, there are also counterpoints such as impacts on vegetation and fauna, which can be mitigated by not opening degradation zones – such as highways for transport.
Vandenhove et al. (2002).	The work presents itself as a financial assessment of short-term planting in areas contaminated by nuclear issues.	Excluding radioactive aspects, the reuse of degraded areas has positive environmental and economic potential.
Narendra et al. (2021).	The study did not use images and georeferenced information to define which degraded areas were most suitable.	The simulation showed that planting species suitable for energy generation also reduced soil degradation.
Shen et al. (2020)	There is no use of georeferenced data.	Evaluates the productivity of species in energy generation and their remediation potential.
Spiess & De Sousa (2016).	The objective of the work was to identify the main barriers to the use of degraded areas in renewable generation, as well as seek mitigating measures. No there is use of georeferenced data .	The researchers conclude that it is extremely important in energy production in these areas to find areas with good resources and good logistical aspects.
Thewys et al. (2010).	The work is not about generating energy but about using degraded areas by livestock farmers.	Out of scope .
Faaij (2022).	The work did not use area selection methodology or any type of georeferencing.	The work defended the use of degraded areas for planting biomass for energy generation – pointing out benefits such as carbon capture, reduced erosion, water retention and restoration of ecosystem services.
Leksono et al. (2021).	The work uses data on degraded areas, but only in quantitative form, without any georeferenced data.	The need to identify which crops are suitable, in terms of lower demand for land quality, for growth in marginal, abandoned and degraded areas was observed.
Bhatt et al. (2016).	There is no use of georeferenced data.	The study discussed the environmental impacts of generating energy through burning wood.
Artati et al. (2019).	The focus is not on any aspect relating to energy generation but on the perception of land owners on the subject.	Producers' interest in planting non-food seeds in degraded areas for bioenergy production has increased.
Koda et al. (2021).	There is no relationship with energy generation.	Out of scope .

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Zhang et al. (2024).	The focus of the study is on measuring soil characteristics. There are no aspects of area selection or focus on energy production.	The results showed that, in addition to the benefits of energy production, there was an improvement in the vegetative conditions of degraded pastures, since the area became restricted.
Nguci et al. (2018).	The work did not take into account degraded areas or the search for these areas.	Need to produce renewable energy globally to reduce carbon dioxide emissions.
Metzger & Huttermann (2009).	The assessment does not use images or georeferenced data, it makes a quantitative assessment based on data from degraded areas.	The work aimed to estimate energy demand for the year 2030 and analyze the possibility of meeting it with bioenergy from plantations in degraded areas.
Gorman et al. (2023).	The study did not work with the selection of areas for energy generation but with the assessment of its impacts on biodiversity.	It aimed to produce renewable energy, which is also positive for biodiversity. This is done through the promotion of methods with less ecological impact and the development of less aggressive infrastructure.
Nowak et al. (2023).	There was no selection of areas or assessment of degraded regions in the methodology.	Out of scope .
Chen & Yang (2022).	The analysis is only of degraded areas, having no relation to energy generation – it is just one of the suggestions for reuse.	Out of scope .
Ogbonnaya , Turan & Abeykoon (2020).	Direction for the thermodynamic operation of photovoltaic panels.	Out of scope .
Szumilas - Kowalczyk & Giedych (2022).	Focus on studies of documents related to territorial planning in Poland.	Out of scope .

Some studies, although excluded for not answering the three questions, presented very relevant information that added to the research or helped to validate the objectives raised. The study by Spiess & De Sousa (2016) presents the importance of finding degraded areas that have good quality of natural resources – such as irradiance and wind speed –, good infrastructure and logistics aspects – distance to transmission networks and highways, elevation suitable terrain, among others. Carrying out this joint analysis is related to a good selection of the area and reduction of failures.

Ott et al. (2021) discussed the impacts on fauna and flora that the opening of a new energy generating point can cause and showed that these can be mitigated by not opening degradation zones – such as highways. This conclusion is in line with the search for regions close to already established highways.

Zhang et al. (2024) focused the study on the evolution of soil characteristics after a degraded pasture received solar panels. Although the focus is on the analysis of vegetation, the results corroborate the positive idea of linking the remediation of a degraded area to energy

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generation since, in addition to producing energy – an undeniable benefit – there was an improvement in the quality of the pasture.

Gorman et al. (2023) observed the impacts on biodiversity at energy generation points. The authors showed that it is possible to produce renewable energy in accordance with good biodiversity practices. One way to avoid impacts due to the installation of infrastructure is to reduce new road openings as much as possible, showing how the methodology of seeking already installed logistics is beneficial to the process.

By analyzing the seven articles accepted after reading them in full, it was possible to gather useful information to answer the questions and validate the objective of the research. Table 3 presents the works, typology, objective and a summary of the most relevant information.

Table 3

Works accepted after full reading and main data collected.

Reference	Type	goal	Case	Information relevant
Vrînceanu , Dumitrașcu , & Kucsicsa . (2022)	PV	Carry out analysis of the best theoretical locations for installing photovoltaic plants in Romania . Afterwards , it was compared with the distribution of the plants existing .	Search for areas in the country.	raster overlay scheme on biophysical, anthropogenic and restrictive factors. The results zoned regions according to their suitability for photovoltaic energy generation and, within this analysis, good values were observed in degraded areas.
Edrisi et al. (2022)	BI	Presenting the possibility of energy reuse, the study aimed to update the updated estimate about the amount of degraded land in India.	Search for areas in the country.	The methodology collected data from several agencies to carry out, after collecting the information, the layers were superimposed and created a suitability ranking based on biophysical criteria. The results presented maps of Indian degraded areas and their potential for biomass cultivation for energy use.
Waite (2017)	PV, EO	The researcher aimed to describe the benefits and quantify the wind and solar potential for energy production on contaminated or degraded land in the USA.	Analysis quantitative just .	The methodology took into account the database of American states that participate in the RPS energy matrix diversification program. The study used quantitative data on the degraded area of these states and calculated the generation potential per state in the photovoltaic and wind typologies. The results showed excellent adherence to the methodology, especially solar.
Adelaja et al. (2010)	PV, EO	The objective of the work was to evaluate the potential for developing types of renewable energy generation and its economic impact in the	Case study .	brownfield areas in the state of Michigan and crossed data with information on solar and wind resources. The results came from overlapping layers to reveal brownfield areas with adequate resources. The authors discussed more about the total energy produced and its generation costs, not focusing so much on

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		American state of Michigan.		the search for the best locations for installing plants.
Donaldson & Lord (2018)	GT	The objective of the work was to evaluate abandoned areas in Glasgow that could be used to generate renewable heating.	Case study .	The work methodology was built based on data about abandoned, contaminated areas and places where landfills are located – or were located. No aspect of infrastructure or resources was taken into account. The results obtained corroborated a map of opportunities. In this case, heating demands were met by up to 80%.
Liu et al. (2016).	BI	The authors' objective was to identify the marginal areas available for the cultivation of energy biomass.	Case study .	The methodology was applied in a region in northwest China where decades of data were used to evaluate changes in land use and occupation, the speed of these changes and determine marginal areas. The results returned the area to planting, but without zoning.
Loeffler, Calkin & Silverstein (2006).	BI	The objective of the work was to estimate biomass production in a specific location, the spatial distribution of the plantation, and the associated costs.	Case study .	The methodology consisted of choosing a study area in the United States, evaluating the forests and modeling the trees to be cut, and then carrying out a series of cost estimates based on biophysical factors. The results focused on cost, in situ treatment and atmospheric carbon sequestration.

Vrînceanu , Dumitrașcu , & Kucsicsa (2022) discussed the enormous importance that the energy sector has in limiting global warming to up to 2°C – a value stipulated in the Paris agreement. Working with the photovoltaic energy sector, the authors sought to analyze the best locations to implement a plant of this type in Romania . For this, the Multicriteria Assessment (MCE) was used, which integrates several factors, positive and negative, such as characteristics of the solar resource, angulation, land use, proximity to residences, roads, among others and combines them to generate suitability maps for expansion. .

In this way, Vrînceanu , Dumitrașcu , & Kucsicsa (2022) performed weighted overlay, where multiple rasters are combined, each with its weight defined according to the importance of the data, thus creating a scale for joint analysis. This approach makes it possible to list the best options by multiplying the factor in question by the weight chosen for all input data, presenting the final adequacy values for each pixel.

The authors took into account biophysical, anthropogenic and – the only restrictive factor – environmental factors, divided into the largest protected areas such as national parks and reserves, presented in Table 4.

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Table 4

Factors, thresholds and their weights chosen for the study by Vrînceanu , Dumitrașcu , & Kucsicsa (2022).

Criteria	Thresholds	Weight
GHR solar radiation (in kWh/m²/year)	Below 1200 is not viable; above 1400 the adequacy is maximum (100%); and there are intermediate values.	28%.
Elevation (in m)	The increase in elevation makes installation difficult and reduces the possibility of energy transmission. Below 100 m, suitability is maximum; and above 1000 is not viable.	5%.
Slope (in °)	The more horizontal the terrain, the better for installing panels. Thus, slopes lower than 2° are 100% suitable, while slopes greater than 16° are unfeasible.	20%.
Average sunshine (in hours)	It is inversely related to the degree of cloud cover in the area, a factor that reduces efficiency. Therefore, the greater the insolation, the greater the efficiency. Below 1800 hours per year is unfeasible and above 2300 it is 100%.	5%.
Average wind speed (in m/s)	Wind speed is a factor that affects the operation and duration of panel materials. Very low speeds are subject to dust accumulation, while very high speeds increase corrosive actions (both harmful). So, speeds medians how 2 and 3 m/s are preferable .	5%.
Land use and occupation	This factor can be favorable or limiting. Land without vegetation or with low vegetation is the most favorable (pasture areas receive the highest weight, 100%). Areas built , with forests or with water they are unfeasible .	10%.
Distance to centers (in km)	How much smaller is better .	5%.
Distance to highways (in km)	How much smaller is better .	5%.
Protection areas	Factor restrictive .	Not applicable .

Source: adapted from Vrînceanu , Dumitrașcu , & Kucsicsa (2022).

The methodology developed by the authors made it possible to zone Romania into zones of "high", "medium", "low or very low" suitability and "inappropriate" with approximate values of 30%, 15%, 5% and 50%, respectively. Furthermore, Vrînceanu , Dumitrașcu , & Kucsicsa (2022) showed excellent values in low-productive areas such as those contaminated such as degraded areas. A high level of suitability was defined in several degraded agricultural areas, abandoned mines and waste dumps.

Vrînceanu , Dumitrașcu , & Kucsicsa (2022) also highlighted that the lack of data such as the existing electricity transmission network, the generation capacity of agricultural land and spatial planning were factors that limited the accuracy of the results obtained.

Edrisi et al. (2022) showed that plantations aimed at energy production have been consolidating themselves as good solutions for restoring degraded areas. Energy production in degraded areas becomes very important as it does not cause conflicts in the food-energy

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production relationship. Thus, the article aimed to update the current estimate of the amount of degraded land in India.

The authors collected biophysical criteria in several categories, worked with land use and occupation, temperature, amount of rain, elevation, slope and soil aspects, without taking into account any data related to infrastructure. Based on these, maps were generated and analyzed together by superimposing the layers.

A map was prepared with degraded areas and several others with their potential for growing energy biomass for a series of crops. Within these, the potential planting area and the averages of atmospheric carbon captured, biofuel produced, calorific potential, carbon, gross biomass and bioenergy were calculated.

Waite (2017) presents the very clear and evident link that exists between energy generation and land use for new facilities. Usually, the choice of locations is almost always directed towards " greenfields ", which is a hyperonym for open spaces, areas with food production, forests, among others.

Furthermore, much is assessed regarding the availability of resources – such as wind and radiation –, terrain conditions, consumer market and other technical-financial aspects. However, Waite (2017) discusses the importance of thinking about energy generation from the most diverse perspectives, including biological, technical and social. Therefore, aiming to improve these factors, a sustainable option lies in the use of thousands of underutilized and degraded lands. This suggestion tackles two problems at once: reusing thousands of degraded kilometers and developing renewable energy sources.

The work sought, among the states participating in the energy matrix expansion program (RPS in the American acronym), to describe the benefits and quantify the wind and solar potential for energy production on contaminated or degraded lands. Waite (2017) took into account quantitative data on the size of the degraded area and physical criteria such as distance to highways and transmission lines and resource availability – wind or solar. To achieve this, the author then created a reference on the size of the project and the thresholds of these criteria for a technically viable project, which can be presented in Table 5.

Table 5

Requirements for installing a new solar or wind energy generating plant.

Solar: reference 7.9 acres to produce 1MW.			
Scale	Irradiance normal direct	Area size	Maximum distance to transmission lines and highways
Huge	>= 5 kWh/m²/ day	>= 40 acres (0.17 km²)	<= 10 miles (16 km)

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Big	>= 3.5 kWh/m²/day	>= 2 acres (0.008 km²)	<= 1 mile (1.6 km)
No network connection	>= 2.5 kWh/m²/day	Not applicable .	Not applicable .
Wind: reference 82.25 acres to produce 1 MW.			
Scale	Wind speed at 80 m	Area size	Maximum distance to transmission lines and highways
Huge	>= 5.5 m/s	>= 100 acres (0.4 km²)	<= 10 miles (16 km)
Big	>= 5.5 m/s	>= 40 acres (0.17 km²)	<= 10 miles (16 km)
1-2 turbines	>= 5.5 m/s	>= 2 acres (0.008 km²)	<= 1 mile (1.6 km)
No network connection	>= 5.5 m/s	>= 0.25 acres (0.001 km²)	Not applicable .

Source: adapted from Waite (2017).

Waite (2017) collected non-georeferenced quantitative information that used as a basis the reference values mentioned in table X and the amount of degraded area in each of the 29 states adopting the RPS. According to the author, if only 10% of all renewable energy potential in degraded areas were installed in states that have RPS, their excess demand could be resolved.

Adelaja et al. (2010) studied the potential of generating renewable energy in brownfields – a popular term in English for generally abandoned or underutilized areas previously used as industrial or commercial facilities, which may or may not be polluted or contaminated. The objective was to evaluate the potential for developing renewable energy and its economic impact in the American state of Michigan.

The authors developed the methodology based on existing brownfield areas in Michigan and overlaid with solar and wind resource data. Proximity to the network, highways or any other infrastructure, social and/or environmental factors were not taken into account. The focus of the results lies on the interpretation of costs. According to the authors, this is still the main debate, as it is not always favorable when compared to conventional energy – which in the USA almost always comes from fossil sources.

Donaldson & Lorde (2018) studied the possibility of regenerating unused areas in areas that generate thermal energy – a solution that aims to solve two socioeconomic problems. The work was a case study for the city of Glasgow and worked with the generation of thermal energy – not electrical – for residential heating.

The authors sought to assess the amount of land that could be available for the generation of renewable thermal energy in brownfield areas , defined by the government. They also selected current or previous landfill installation areas as these are much larger in size. The comparison of these was made only with demand, without taking into account any type of infrastructure and resource aspects, looking for renewable heating options.

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Based on the maps of demand and areas of interest, an overlay was made, creating a final map of areas of opportunity. The results showed a capacity to meet the heating need of approximately 80%.

Liu et al. (2016) discussed the importance of the growth of energetic biomass not only for its purpose, but also for the reduction of atmospheric carbon dioxide and, consequently, in ensuring sustainable development. The work used a historical series – 30 years – of high resolution to identify the marginal areas available for planting a specific crop with a view to generating energy from its biomass. No data relating to infrastructure or socio-environmental aspects were used.

The researchers presented the results for the Chinese area in terms of area available for planting – without zoning –, expected biomass production, amount of carbon dioxide removed from the atmosphere and cultivation time. The study then concluded that the chosen crop – Miscanthus – is suitable for growth in these unused areas.

Loeffler , Calkin & Silverstein (2006) analyzed the capacity to use biomass in fuel generation. The focus was on estimating biomass production in a specific location, the spatial distribution of trees in Montana and the associated costs. To achieve the objective, the authors assessed the conditions of existing forests and carried out modeling based on the forest inventory. They also took into account the trees to be cut, cultivation costs, eligible areas based on forest type, fire risk, slope , proximity to highways and transportation costs.

The results presented were more focused on the cost of biomass production, the possibilities of on-site or off-site treatment and the reduction of carbon in the atmosphere. The analysis, despite collecting data on forests in a georeferenced way, was more quantitative, raising values and volumes.

5 CONCLUSION

Based on the questions raised, all 29 articles read in full were able to contribute to the research. Obviously, the seven accepted for review were those that actually had a direct association with the topic and were further explored.

Regarding the first question – Are there studies that discuss the opening of new energy generating units, using renewable typologies, in georeferenced degraded areas? – The studies highlighted in the seven articles accepted for review discussed this issue in depth, agreeing that this is a focal theme in the opening of new energy generating sites.

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With regard to the second – If yes, what typologies were addressed by the authors – the seven studies highlighted in the accepted articles were divided as follows: one discussed geothermal generation, one exclusively addressed solar generation, two jointly addressed the possibility of photovoltaic and wind generation, three discussed the use of degraded areas through biomass generation.

The third question is of great importance as it discusses the main points analyzed in the studies for choosing an area. Vrînceanu , Dumitrașcu , & Kucsicsa . (2022), the most complete study in terms of number of variables considered, took into account quantities on the resource to be explored, elevation data, land use and occupation and distance to cities and highways, in addition to a restrictive factor that would be protection areas.

In this study, it was pointed out that the lack of data such as the existing electricity transmission network, the generation capacity of agricultural land and territorial planning were factors that limited the accuracy of the results obtained.

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