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Exploring the Role of Geospatial Technologies in Renewable Energy Potentials: An Overview Study

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Abstract

This review study explores the pivotal role of geospatial technologies in advancing renewable energy planning and management. Beginning with an overview of renewable energy resources, including solar, wind, hydroelectric, and biomass energy, the review emphasizes the importance of transitioning towards sustainable energy sources to address climate change and enhance energy security. It highlights the significance of these technologies in capturing, analyzing, and visualizing spatial data for renewable energy applications. Through case studies and best practices, the review illustrates how geographic information system (GIS), and remote sensing are utilized for site selection, resource assessment, infrastructure optimization, and environmental management across various renewable energy projects. It provides a comprehensive overview of relevant literature, identifies gaps, or challenges in current knowledge, and offers insights for future research directions. The review paper help researchers and scholars stay informed about the state of the field and provide a synthesis of existing research findings.

Keywords: Energy planning, Geographic Information Systems (GIS), Remote Sensing, Spatial Data.

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1. Introduction

Considering the global calls at the political and environmental levels to reduce fossil energy emissions, we are witnessing constructive trends in the planning, production and storage of renewable energy. In fact, there are two main factors driving the development of renewable energy methods: (1) the risk of climate change resulting from the burning of traditional fossil energy sources such as oil and gas, and (2) the need for countries to secure their energy needs to ensure their stability and security1.

Renewable energy is generally defined as energy resulting from the use of continuously renewable natural sources such as solar radiation, wind, sea waves, tides, rivers, subsoil heat, etc2. The natural and environmental diversity of these sources on Earth has made them possible to be used as an energy source, making them accepted as an alternative source of energy of traditional sources3. To this end, the availability and feasibility of using these sources in terms of space and time must be studied and evaluated, which can be achieved by drawing on the great potential of geospatial technologies. The geospatial technologies, encompassing geographic information systems (GIS), remote sensing, global positioning systems (GPS), and spatial analysis tools, have revolutionized the landscape of renewable energy research and development. By integrating spatial data with advanced computational techniques, geospatial technologies offer unparalleled insights into the spatial and temporal dynamics of renewable energy resources, facilitating informed decision-making across the entire energy value chain4.

The introduction of geospatial technologies in the renewable energy sector is improving. There is much research that has used these technologies in this area, especially at local scales. These technologies have been used in areas such as assessment of renewable energy potentials5, energy consumption modeling6, energy infrastructure construction projects7, energy demand estimation8, and site selection planning9. Based on all these potentials of geospatial technologies in the field of renewable energy, there is a need for a comprehensive study to explore the relevant literature that integrated these technologies in a renewable energy sector and identifies gaps in current knowledge and offer insights for future research directions.

From a broader perspective, the integration of energy production systems with geospatial technologies will enable us to build a full picture of future energy production, generation, and storage systems10. This will enable a broader understanding of temporal and spatial changes in energy demand, the availability and efficiency of conventional and renewable energy sources, storage capacities and loads of energy infrastructure, and finally the profitable returns of investment in this area.

The methodology employed in this overview study relied on searching the literature on Google Scholar database using the related keyword queries. Only peer-reviewed research articles were selected based on the research objectives. The main keywords used for searching included "geospatial technologies, renewable energy potentials and challenges, renewable energy mapping, suitability analysis of renewable energy", covering the period from 2015 to 2024 with focus on the most recent articles. The relevant articles were reviewed and screened, and the results are discussed in the following sections.

2. Major renewable energy sources

There are many renewable energy sources that allow for the possibility of benefiting from these sources at the local, regional, and even global spatial levels. The use of renewable energy in the production of electrical energy is of great importance compared to other traditional sources such as (i) they do not produce greenhouse gases, (ii) do not cause land degradation or pollution, (iii) reduces the need to extend power transmission lines, accelerates the process of supplying remote areas with electrical energy, and thus increases the regional coverage of electrical energy, (iv) increases the sense of energy security and availability, contributes to reducing unemployment and improving the standard of living of the employed population. The most common renewable energy sources are as follows:

2.1 Hydropower

It refers to the enormous energy generated by the runoff of water in rivers or dams in the production of electrical energy. Hydroelectricity generation increased by almost 70 TWh (up close to 2%) in 2022, reaching 4 300 TWh. Hydropower remains the largest renewable source of electricity, generating more than all other renewable technologies combined11. In general, the production of electrical energy from hydropower sources is characterized by its sustainability compared to other renewable sources such as the sun and wind due to the possibility of exploiting it continuously at a rate of 24 hours a day.

2.2 Wind Energy

Wind is a source of energy production through the use of large fans and generators that convert the energy generated by the movement of the fans into electrical energy. Wind energy is the cleanest renewable energy source because it does not produce pollutants and its impact on the surrounding environmental landscape is very limited. Currently, wind energy ranks second as one of the renewable energy sources used in the production of electricity globally. In 2022 wind electricity generation increased by a record 265 TWh (up 14%), reaching more than 2100 TWh. This was the second highest growth among all renewable power technologies, behind solar PV11.

2.3 Solar Energy

The sun is a source of two main types of energy, photovoltaic and thermal energy, which are released in all directions, with a fraction reaching the Earth's surface because of the interactions of solar radiation with the Earth's atmosphere. In general, at the global level, location in relation to latitudes is the main factor in determining the variation in the amount of energy reaching the Earth's surface. At the regional or local level, topography elements such as altitude, slope, slope direction, terrain shades and local weather elements play a major role in the variation in the amounts of energy connected between geographical locations. The amount of energy affects many vital processes such as evaporation, transpiration, soil and air temperature, snow melting, photosynthesis and others. Solar energy is considered one of the most distinguished alternative energy sources in the world, especially in the second decade of the twenty-first century. This was due to the great scientific advances in the manufacture of solar panels, which have become less expensive and more efficient. In 2023, solar PV alone accounted for three-quarters of renewable capacity additions worldwide11.

2.4 Bio Energy

Bioenergy is defined as the energy produced by the use of plant and animal organic residues in energy production. The trend is to use bioenergy as an alternative and sustainable source of hydrocarbons, especially in transportation such as the use of biodiesel and bioethanol, as well as the use of firewood for heating. The use of modern bioenergy has increased on average by about 3% per year between 2010 and 2022 and is on an upward trend. More efforts are needed to accelerate modern bioenergy deployment. Overall, the contribution of bioenergy to the end of 2015 was about 2% of global electricity11.

2.5 Other Renewables

Other renewable energy sources include geothermal power, tidal power oceanic wave and, which together account for 0.5% of global electricity production until the end of 202311. In general, these sources can provide quantities of electrical energy theoretically estimated at 32 PWh/y if the necessary scientific and technical means are available. In fact, this technology is still under development, and it is too early to estimate when it will contribute effectively to comprehensive energy plans11.

3. The Role of Geospatial Techniques in Renewable Energy

In fact, there are several studies that have relied on geospatial techniques in planning and managing the process of building, producing, and evaluating renewable energy. The role of these technologies in the field of renewable energy can be represented in two main axes, the first is concerned with evaluating renewable energy sources and determining their geographical distribution. The second is the process of selecting sites for the construction of renewable power plants based on renewable energy sources.

3.1 Mapping of Renewable Energy Resources using Geospatial Technologies

The process of determining the geographical distribution of renewable energy sources is very important as many human activities depend on them such as agriculture, environmental sciences, building construction, photovoltaic energy, land management, and others. In this context, geospatial techniques can provide information showing the quantitative and qualitative distribution of different renewable energy sources.

In the field of solar energy, the use of remote sensing techniques is one of the best. It provides continuous and low-cost data and covers large geographical areas compared to traditional methods that rely on ground stations12. This has made it possible to build a clear and accurate geographical database that contributes to estimating supply and demand levels, thus contributing to the planning of the energy sector. Remote sensing techniques can be used in indirectly estimating the amount of solar radiation reaching the Earth's surface in a specific unit area, or the so-called irradiance13. Where the factors affecting the amount of solar radiation such as water vapor, the amount of particles and clouds in the atmosphere, in addition to topographic information such as altitudes, degrees of slope and their directions are estimated by remote sensing data. It is then used with terrestrial climate data to calculate the amount of solar radiation over large geographic areas14. This has been applied in many studies globally and using different satellite-based remote sensing data such as MODIS15 and METOSAT16, NOAA/AVHRR17 which provide information at wide regional scales. In addition, high resolution remote sensing data such as QuickBird and Lidar have been used in estimating the quantities of solar radiation available at the urban level from rooftops18.

Regarding GIS, there are many mathematical models used in solar radiation estimation that are compatible with GIS software. One of the first such models is SolarFlux19 which has been included in the well-known Arc/Info software as a built-in toolbox. Another model, known as Solei, has been added to IDRISI20. Other methods are more advanced and commonly used, such as Solar Analyst which has been developed and added as an ArcGIS toolbox21. This toolbox can be used to produce maps of solar radiation distribution at the regional level based on digital elevation models (DEM). Another model is the r.sun model which was developed as a tool for estimating solar radiation in different weather conditions (clear and cloudy) and for geographical environments with different topography22. The r.sun model was based on the European Solar Radiation Atlas equations and was used to estimate the solar potential of a photovoltaic system in Central and Eastern Europe. This model was also added to the GRASS GIS program, allowing the use of the necessary Spatial Interpolation techniques in the data preparation process22.

It is noteworthy that the r.Sun model can be easily used to measure solar radiation in the long term and on various geographical scales from local to regional and even global.

In wind energy, the use of SOnic Detection and Ranging (SODAR) and LIght Detection and Ranging (LIDAR) are the main remote sensing techniques in obtaining accurate measurements of wind speed and direction10. This is because traditional methods based on mast devices at climate stations can no longer provide the complete information that can meet the tremendous development in the sizes and power of turbines and wind fans today. SODAR and LIDAR techniques are used to generate sound or light waves and detect the backscattered waves to transceivers. SODAR and LIDAR technologies provide direct measurements of wind speed based on the calculation of what is known as Doppler displacement23.

SODAR technology measures wind speed and direction at multiple atmospheric altitudes using ground-based remote sensors that send a series of sound waves at frequencies ranging from 20004000- Hz upwards at three different angles in the atmosphere. The sound wave disperses in the atmosphere in multiple directions due to temperature differences and atmospheric fluctuations, and a small part of it is returned to a directional-sensitive microphone24. The beginning of this technique was in the eighties of the twentieth century for the purposes of environmental conservation and air pollution studies before its use in the field of wind energy. The height at which wind speed is measured is determined by calculating the time difference between the moment the wave is transmitted and the moment of receiving the return from them. Wind speed is calculated according to the Doppler equation as the sum of the frequency difference between the transmitted frequency and the backscattered frequency. This method is known as mono-static where both transmitter and receiver are operated together. Another method called bistatic is where transmitters and receivers are 100200- m apart. The use of LIDAR technology is to sense the movement of air in the atmosphere by light radiation released from the surface of the Earth, either in the form of a continuous wave or in the form of pulse. LIDAR devices detect the change in frequency and wavelength of radiation released and returned to the receiver, or what is known as Doppler shift. LIDAR devices offer multiple information on winds at different altitudes and angles with high accuracy25.

In fact, the use of wind speed measurements based on remote sensing data is essential both in coastal and inland locations for various purposes including assessment of wind sources, development of wind farm projects, measuring the efficiency of wind turbines, financing for wind energy projects, and wind modeling and drawing wind atlases. The accurate readings of wind speed are essential as an error of more than 1% in calculating the average wind speed may result in an error of more than 3% in estimating the average amount of energy that can be generated. Currently, SODAR and LIDAR devices can measure average wind speed, average wind direction and wind turbulence in ten minutes at altitudes between 20 and 200 meters above the ground. These devices are also characterized by their low cost and ease of transport. Compared with the construction of traditional fixed climatic stations10.

In the field of hydropower, the use of remote sensing and GIS is essential in hydrological modelling26 they are used for identifying and measuring of streams and estimating of water runoff, which is the main influencing factor in hydroelectric projects27. In addition, they provide information on the types of soils, plants, land uses, topographic and geological characteristics of the area, which are used in the field of determining the sites for the construction of dams. This is mainly based on the evaluation of high-resolution DEM such as those derived from Lidar or Stereoscopic IRS or SPOT satellite images, as well as the medium and high spatial resolution data from Landsat, Sentinel and QuickBird among other satellite data. These technologies provide more comprehensive information and estimates of river flow quantities compared to information from spatially limited hydroclimate stations. It also facilitates the collection and analysis of large amounts of data together within a single integrated geographic database28,29. Studies indicate that there have been significant developments in the field of hydropower in the last fifteen years due to the great progress in the field of geospatial technologies, where it has become possible to assess the potential of hydropower for large water basins in high detail especially if we know that this data has become free in many countries of the world10. It is noteworthy that many countries of the world, such as Canada, the United States of America, Italy, Norway, and others, have worked to reassess the hydropower capabilities of their water basins based on high-resolution spatial information provided by geographic information systems and remote sensing. They also developed many programs and tools with the aim of locating hydropower and disseminating them in the form of tools available on the Internet as Web-GIS tools. This is termed as the Atlas of Microscale Hydropower Sources for Public Use, which can be used and applied in other countries30.

In general, the following components should be taken into account when using GIS and remote sensing in assessing hydropower potential: (i) identifying and collecting spatial and non-spatial hydrological characteristics in a single geographic database, (ii) developing of a digital elevation model for estimating the hydropower potential, (iii) developing tools to evaluate small hydropower projects and then integrate them into an integrated geographic information system, and (iv) presenting the results of the assessment using GIS and making them available online.

In the field of bioenergy, remote sensing and GIS have been used to estimate the quantities of organic content of agricultural crop residues, forests, and prairies through the production of land use maps to estimate the potential of bioenergy by assessing the quantitative and qualitative distribution of available bioenergy sources31. The geographic database of bioenergy projects usually includes data on land use and cover, topographic information, administrative boundaries, climate data and maps, road network, digital terrain models, geological maps and population distribution. After building the geographical database, the places where plants remain, and other vital sources are collected and determined to estimate the organic content available for energy production. This method has been used in many studies, for example, Zhang et al., (2008)32 assessed the potential bioenergy production on urban marginal land in 20 major cities of China using multi-view high-resolution remote sensing data. Manolis et al., (2018)33 used GIS and remote sensing to assess the spatial limitations in forest biomass harvesting using for an ecological and sustainable bioenergy framework. Van Holsbeeck, and Srivastava (2020)34 explored the feasibility of locating biomass-to-bioenergy conversion facilities using spatial information technologies in Queensland, Australia. Bharti et al., (2021)35 provided an overview on GIS application for the estimation of bioenergy potential from agriculture residues. It should be noted that geospatial techniques are not used in the direct monitoring of biofuels, but are used to monitor land use and change, and to map

the geographical distribution of agricultural crops that are most commonly used in biofuel production at local levels such as using small-scale SPOT5, IKONOS and QuickBird data with less than 10 meters of spatial resolution, and regional levels such as Landsat satellite data. (1560- meters) or globally such as MODIS and SPOT satellite data (250-1000 meters)36,37.

3.2 Site Selection and Suitability Analysis of Renewable Energy Sources based on Geospatial Technologies

The process of selecting the right location for power plants requires a full assessment of the technical, economic, social, and environmental issues of the target area. As a result, specialists in the industrial and environmental sectors have developed several methods for establishing power plants based on renewable energy, starting from traditional methods based on local visits and field surveys to the use of advanced methods of using geospatial technologies. The use of these technologies has greatly facilitated the process of choosing the optimal site in several areas, including the process of selecting the locations of renewable electric power plants. The importance of these techniques lies in the fact that they save a lot of effort and money, in addition to providing analytical tools and comprehensive information about the target area. Also, the amount of spatial and non-spatial information contributing to the location of renewable electricity production plants cannot be combined without the use of geographic information systems. Perhaps the most prominent method used in this field is the multi-criteria analysis method (MCDM) which has been used in many studies38.

The role of GIS does not stop at this point, but it is used in the preparation, collection, and arrangement of spatial and descriptive data necessary for such projects, supported by the comprehensive satellite and aerial data and images provided by remote sensing techniques for the study area. Perhaps, the most prominent of this information is the provision of comprehensive and detailed maps of land uses and information on various topographic aspects such as slope, elevation, surface directions, etc. In addition to its role in mapping distribution of the renewable energy resource as already mentioned.

Based on reviewing the published work in this field, we can summarize that the implementation of GIS and remote sensing in the selection of renewable energy project sites usually includes the following stages:

- Formation of a team consisting of academic, governmental, and industrial experts who participate in the process of identifying and evaluating the criteria affecting the selection of renewable energy plant sites.
- Identify technical, economic, social, and environmental obstacles to the exploitation of renewable energy to identify inappropriate areas.
- Identify and evaluate spatial and non-spatial criteria affecting renewable energy potential.
- Determine the weights of evaluation criteria according to their importance in influencing the selection of renewable energy sites.
- Building a land suitability analysis model for the construction of renewable energy plants.
- Building geospatial and non-spatial databases for factors affecting the selection of sites.
- Determine the method and tools of layers integration in GIS environment.
- Preparing a land suitability map for areas for renewable energy exploitation graded from highest to least important based on standardizing and reference bases.
- Finally, provide decision-makers with final maps of optimal sites for final decisions.

Table (1) highlights example case studies on the role of geospatial technologies in the field of renewable energy.

Table (1): Example case studies on the role of geospatial technologies in the field of renewable energy

Reference	Geographical focus	Renewable energy investigated	Geospatial tools and models	Main findings
Abdi et al., (2024)[39]	Iran	wind and solar	GIS-AHP-GAMS	Proposed optimal power plants to minimize unsupplied energy in an industrial area in Iran.
Yousefi et al., (2024).[40]	Iran	wind	AHP- MCDM	Identified wind farm sites using at regional scale with environmental responsibility.
Rekik, and El Alimi, (2024)[41]	Tunisia	solar and wind hybrid	GIS-based MCDA	Defined the optimal area for hybrid system which has the highest potential in terms of available resources and compatibility.
Akpan et al., (2024)[42]	Nigeria	wind	numerical and metaheuristic procedures and remote sensing	Provided technical and performance assessments of wind turbines in low wind speed areas using numerical, metaheuristic and remote sensing procedures

Reference	Geographical focus	Renewable energy investigated	Geospatial tools and models	Main findings
Hassan et al., (2024)[43]	Iraq	Biomass-PV-Wind hybrid	GIS-based MCDA	Evaluated the energy, economic, and environmental aspects of solar-wind-biomass systems to identify optimal locations in Iraq
Sapkota et al., (2024)[44]	India	Wind	F-AHP (Fuzzy-Analytical Hierarchy Process)	Assessed wind farm site suitability using geospatially explicit multi-criteria approach: A case study of South Sikkim, India
Yildiz, (2024)[45]	Turkey	Wind	GIS-based MCDA	wind farm site selection was identified using spatial multi-criteria decision-making approach

Reference	Geographical focus	Renewable energy investigated	Geospatial tools and models	Main findings
Sachit et al., (2024)[46]	Iraq	wind–solar	GeoAI-based multidisciplinary model	Developed a novel GeoAI-based multidisciplinary model for spatiotemporal decision-making of utility-scale wind–solar installations: To promote green infrastructure in Iraq
Ferreira et al., (2023)[47]	Brazil	solar, wind and hybrid	Machine Learning-based models	Developed a new index to evaluate renewable energy potential of solar, wind and hybrid generation in Northeast Brazil
Alotaibi and Anzah, (2023)[48]	Kuwait	hybrid wind–solar	AHP–GIS	Identified the suitable sites for hybrid wind–solar in a hot desert region the Kuwaiti desert
Aghaloo et al., (2023)[49]	Bangladesh	solar-wind hybrid	GIS-based BWM-fuzzy logic	Defined the optimal sites for the solar-wind hybrid renewable energy systems in Bangladesh
Samak, (2023)[50]	Saudi Arabia	solar and wind	MCDM-GIS	Applied multi-criteria analysis for solar and wind power modelling for two cities (i.e., Makkah and Jeddah) in Saudi Arabia

Reference	Geographical focus	Renewable energy investigated	Geospatial tools and models	Main findings
Alhammad et al., (2022)[51]	Saudi Arabia	solar	MCDM-GIS	Identified solar site potential in Al-Qassim region in Saudi Arabia using GIS and remote sensing
Gerbo et al., (2022)[52]	Ethiopia	solar	MCDM-GIS	Modeled the grid-connected solar power potential sites in East Shewa Zone, Ethiopia
Effat and El-Zeiny, (2022)[53]	Egypt	hybrid solar wind	MCDM-GIS	Selected the optimum sites for hybrid solar-wind energy in Assiut Governorate, Egypt
Hazaymeh et al., (2018)[54]	Jordan	Solar	GIS-Fuzzy	Performed a regional scale photovoltaic site selection based on geospatial techniques in Jordan

4. Challenges Facing the Implementation of Geospatial Techniques in the Field of Renewable Energy

Although geospatial techniques have been used in many renewable energy studies and projects around the world, there are some challenges that continue to slow down the widespread use of these technologies in this field55. One of the most prominent of these challenges is related to the availability of accurate data, which is one of the most prominent challenges in all studies and projects that relied on GIS and remote sensing. Often, data may be available, but their cost is high. Or they may not be available by producers, or

not available at all, prompting the user to produce their own data. This, in turn, may pose another challenge related to the accuracy of the data due to the different capacities between its producers, and the lack of specific, agreed standards for data production56.

Another challenge is the extent to which geospatial and other factors affecting the production of the power grid can be combined. For example, electric power projects focus on the topological characteristics of the electricity grid and often overlook the topographical characteristics of the region. This requires the integration of GIS and remote sensing more effectively into such projects10. But we must not deny that such an integration is not easy since both models of energy systems and spatial analysis and modeling processes are very complex in terms of the need to integrate many data and standards to simulate actual reality as much as possible and with the least possible simplification. With the aim of achieving more sustainable solutions that can often be difficult57. In addition, there are other challenges related to the economic and social factors and conditions of countries58. In many countries, especially developing countries, the economic aspect is the most prominent challenge in the field of renewable energy. Add to this the social factor of community acceptance, privacy issues and private land ownership, which are also challenging aspects of energy projects in both developed and developing countries.

A particular challenge in bioenergy is mainly related to land-use changes from organic-rich environments such as forests and prairies to biofuel crops with lower organic content, which in turn can raise emissions. Other challenges include the loss of natural biodiversity, increased erosion and water pollution and increased global food costs59. Nevertheless, bioenergy projects can be used for land reclamation and used to grow some biofuel-rich crops60.

5. The Future Horizon of Geospatial Technologies in The Field of Renewable Energy

Based on the above challenges, some prospects for the use of geospatial technologies in renewable energy can be determined as follows:

· In the field of providing accurate data: due to the multiplicity of data necessary for renewable energy projects, there must be specific standards, foundations, and legislation to be followed for the production, use, distribution, and exchange of this data between producers and users. GIS is thus enhancing the data integration process61. As mentioned above, the most prominent challenges facing renewable energy projects are related to the availability of a large and unified database that includes all the spatial and non-spatial information necessary for these projects. Due to the lack of such rules in many countries of the world, this field is one of the most important future horizons for investment in GIS and remote sensing for renewable energy projects.

· There is a global trend towards the idea of "open data", which is data that is available to users free of charge and without any barriers. However, many data producers still oppose this idea. This is mainly related to the so cold Open Government Data62 which has been partially started in in many countries such as the United States, the United Kingdom, Germany, and Austria.

· Another way to ensure data collection on renewable energy is to allow citizens to contribute via open internet applications, especially with the great advances in the field of smartphones and tablets. Which enables data collection spatially and directly. Although this data may be less accurate than that collected by specialists, it can contribute significantly to energy projects. This method is known as volunteered geographic information or People as Sensors56. This method has three basic advantages such as (i) increasing the ease of access to geographical databases by understanding the structure of open databases, (ii) increasing the amount of available data, which has so far remained the monopoly of its providers, and (iii) due to the increase in the number of Internet users, the use of GIS programs and tools is not limited to a limited number of specialists, and this will help increase feedback from users to applications, which pushes towards further development63. It should be noted that information that can be provided by the public may include information on storage methods, micro-energy projects (e.g., households), data on consumption volumes, some information from private meteorological stations, etc64.

· Develop a common and unified data model through which data related to renewable energy can be collected and stored and standardized with GIS software and tools. Although there are some efforts in this field, there are still no general solutions that combine scientific research institutions, the public sector and energy companies. Such standardized models will help in the process of integrating data from different sources, which can include data on the capabilities of renewable energy sources. Energy transmission networks, climate data, population and housing statistical data, three-dimensional models, digital elevation models, energy storage means, remote sensing data, and others. All this data must be in the form of raster or vector data in addition to attribute data that work together to build an integrated geographic information system for renewable energy.

· In addition to the method of integrating data from different sources, another method is to process each type of raw data separately, and then a process of integrating the processed data into the GIS environment. This is usually done depending on the nature and structure of this data and the requirements of the analysis procedures. This reduces the consumption of computing storage capacity and increases the flexibility of the data response to the standards required for renewable energy projects. It can be said that the use of spatial data in the energy sector has not reached that high level as in other applications, so this is one of the future fields of research in renewable energy research65.

· Other future research areas in the renewable energy sector include three-dimensional modeling of buildings to calculate the quantities and capacities of renewable energy, and to calculate the amount of energy demand. The area of research here is the development of innovative concepts for the development of urban heating systems and the expansion strategies of power transmission networks, which are the main areas of research targeted66. In addition, the use of three-dimensional analysis is clearly growing to meet some of the future challenges of analyzing the high-resolution building (e.g. Lidar data), the inclusion of building characteristics such as windows, exterior walls and internal networks in energy estimates, and considerations of three-dimensional characteristics of power generators from renewable energy sources67. Although there are separate studies on these topics, there are still no studies that combine them into one integrated system.

Conclusion

The integration of geospatial technologies has revolutionized the renewable energy sector, providing powerful tools for site selection, resource assessment, infrastructure optimization, and environmental management. Through a spatial analysis, data visualization, and decision support systems, GIS and remote sensing enable stakeholders to make informed decisions, minimize environmental impacts, and maximize the efficiency and sustainability of renewable energy projects. This study provides an overview of the role of geospatial technologies including geographical information systems and remote sensing in the field of renewable energy. Two main basic subjects were explored (i) the use of geospatial technologies in providing the data needed for identifying renewable energy sources and (ii) the role of these technologies in defining the optimal sites for renewable energy projects. This review showed the importance of the availability of accurate and high-quality spatial data for effective development of energy projects and its capabilities, especially if they are combined in one work environment. The process of modelling this data will contribute to a broader understanding of the demand for energy, whether conventional or renewable, as well as a broader understanding of the infrastructure, capacity issues and economic benefits of renewable energy projects. The review also discussed some of the most prominent challenges facing the use of remote sensing and GIS in the field of renewable energy and the most important portals of future visions and research in this field.

استكشاف دور التقنيّات الجغرافيّة المكانيّة في إمكانات الطاقة المتجدّدة: دراسة عامّة

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ملخّص

تستكشف هذه الدراسة الدور المحوري للتقنيّات الجغرافيّة المكانيّة في تعزيز تخطيط الطاقة المتجدّدة وإدارتها حيث تبتدئ بإلقاء نظرة عامة على موارد الطاقة المتجدّدة، كالطاقة الشمسية وطاقة الرياح والطاقة الكهرومائية والطاقة الحيوية، ثمّ تستعرض أهمية الانتقال نحو مصادر الطاقة المستدامة؛ للتصدي لتغير المناخ وتعزيز أمن الطاقة. وتسلط هذه المراجعة الضوء على أهمية هذه التقنيات في تحليل البيانات المكانية واستخداماتها في تطبيقات الطاقة المتجددة، وتقدم مناقشةً لدراسات الحالة وأفضل الممارسات في كيفية استخدام أنظمة المعلومات الجغرافية والاستشعار عن بعد في اختيار المواقع، وتقييم الموارد، وتحسين البنية التحتية، والإدارة البيئية عبر مختلف مشاريع الطاقة المتجددة. وتحدد هذه الدراسة الثغرات أو التحديات في المعرفة الحالية في هذا المجال، بالإضافة إلى تقديم رؤى لاتجاهات البحث المستقبلية. وتساعد أوراق المراجعة البحثية هذه في إبقاء الباحثين والعلماء على اطلاع مستمرّ بكلّ ما هو مستجدّ في هذا المجال، وتقدّم توليفة من نتائج البحوث الحالية بما يخدم الأعمال المستقبلية لاستخدامات التقنيات الجغرافية المكانية في مجال الطاقة المتجددة.

الكلمات المفتاحيّة: الاستشعار عن بعد، نظم المعلومات الجغرافيّة، تخطيط الطاقة، البيانات المكانيّة.

Note:

1 Østergaard, P. A., Duic, N., Noorollahi, Y., & Kalogirou, S. (2022). Renewable energy for sustainable development. Renewable Energy, 199, 11451152-.

2 Capareda, S. (2019). Introduction to renewable energy conversions. CRC Press.

3 Qazi, A., Hussain, F., Rahim, N. A., Hardaker, G., Alghazzawi, D., Shaban, K., & Haruna, K. (2019). Towards sustainable energy: a systematic review of renewable energy sources, technologies, and public opinions. IEEE access, 7, 6383763851-.

4 Elkadeem, M. R., Younes, A., Sharshir, S. W., Campana, P. E., & Wang, S. (2021). Sustainable siting and design optimization of hybrid renewable energy system: A geospatial multi-criteria analysis. Applied Energy, 295, 117071.

5 Cevallos-Sierra, J., & Ramos-Martin, J. (2018). Spatial assessment of the potential of renewable energy: The case of Ecuador. Renewable and Sustainable Energy Reviews, 81, 11541165-.

6 Groppi, D., de Santoli, L., Cumo, F., & Garcia, D. A. (2018). A GIS-based model to assess buildings energy consumption and usable solar energy potential in urban areas. Sustainable cities and society, 40, 546558-.

7 Alhammad, A., Sun, Q., & Tao, Y. (2022). Optimal solar plant site identification using GIS and remote sensing: framework and case study. Energies, 15(1), 312.

8 Mishra, T., Rabha, A., Kumar, U., Arunachalam, K., & Sridhar, V. (2020). Assessment of solar power potential in a hill state of India using remote sensing and Geographic Information System. Remote Sensing Applications: Society and Environment, 19, 100370.

9 Hazaymeh, K., Zeitoun, M., Al-Rawabdeh, A., & Al-Sababhah, N. (2018). A regional scale photovoltaic site selection based on geospatial techniques. Jordan Journal of Earth and Environmental Sciences, 9(1), 4756-.

10 Avtar, R., Sahu, N., Aggarwal, A. K., Chakraborty, S., Kharrazi, A., Yunus, A. P.,... & Kurniawan, T. A. (2019). Exploring renewable energy resources using remote sensing and GIS—A review. Resources, 8(3), 149.

11 WEC (World Energy Council) 2024, World Energy Resources, Available online: https://www.iea.org/energy-system/renewables/hydroelectricity#tracking (accessed on 2 March, 2024).

12 Zhu, L., Suomalainen, J., Liu, J., Hyyppä, J., Kaartinen, H., & Haggren, H. (2018). A review: Remote sensing sensors. Multi-purposeful application of geospatial data, 1942-.

13 Rahman, M. M., & Zhang, W. (2019). Review on estimation methods of the Earth's surface energy balance components from ground and satellite measurements. Journal of Earth System Science, 128, 122-.

14 Masoom, A., Kosmopoulos, P., Bansal, A., & Kazadzis, S. (2020). Solar energy estimations in india using remote sensing technologies and validation with sun photometers in urban areas. Remote Sensing, 12(2), 254.

15 Bellaoui, M., Bouchouicha, K., & Oulimar, I. (2021). Estimation of daily global solar radiation based on MODIS satellite measurements: The case study of Adrar region (Algeria). Measurement, 183, 109802.

16 Kariuki, B. W., & Sato, T. (2018). Interannual and spatial variability of solar radiation energy potential in Kenya using Meteosat satellite. Renewable energy, 116, 8896-.

17 Fallahi, S., Amanollahi, J., Tzanis, C. G., & Ramli, M. F. (2018). Estimating solar radiation using NOAA/AVHRR and ground measurement data. Atmospheric Research, 199, 93102-.

18 Andrade, A. M. D., Michel, R. F. M., Bremer, U. F., Schaefer, C. E. G. R., & Simões, J. C. (2018). Relationship between solar radiation and surface distribution of vegetation in Fildes Peninsula and Ardley Island, Maritime Antarctica. International Journal of Remote Sensing, 39(8), 22382254-.

19 He, Y. L., Wang, K., Qiu, Y., Du, B. C., Liang, Q., & Du, S. (2019). Review of the solar flux distribution in concentrated solar power: non-uniform features, challenges, and solutions. Applied Thermal Engineering, 149, 448474-.

20 Siddiqui, A., Joshi, D. K., Rehman, S., Kumar, P., & Devadas, V. (2020). A solar intensive approach for smart environment planning in Gandhinagar, Gujarat. Smart Environment for Smart Cities, 197238-.

21 Choi, Y., Suh, J., & Kim, S. M. (2019). GIS-based solar radiation mapping, site evaluation, and potential assessment: A review. Applied Sciences, 9(9), 1960.

22 Liang, J., Gong, J., Xie, X., & Sun, J. (2020). Solar3D: A 3D Extension of GRASS GIS r. sun for Estimating Solar Radiation in Urban Environments.

23 Torres Junior, A. R., Saraiva, N. P., Assireu, A. T., Neto, F. L., Pimenta, F. M., de Freitas, R. M.,... & Oliveira, D. Q. (2022). Performance Evaluation of LIDAR and SODAR Wind Profilers on the Brazilian Equatorial Margin. Sustainability, 14(21), 14654.

24 Khan, K. S., & Tariq, M. (2018). Wind resource assessment using SODAR and meteorological mast–A case study of Pakistan. Renewable and Sustainable Energy Reviews, 81, 24432449-.

25 Chaurasiya, P. K., Azad, A. K., Warudkar, V., & Ahmed, S. (2021). Advancement in remote sensing of wind energy. In Advances in Clean Energy Technologies (pp. 207233-). Academic Press.

26 Fasipe, O. A., Izinyon, O. C., & Ehiorobo, J. O. (2021). Hydropower potential assessment using spatial technology and hydrological modelling in Nigeria river basin. Renewable Energy, 178, 960976-.

27 Yevalla, G. M. S., Seidou, D. N., Ngoc, B. V., Hoi, T. V., & Tabod, T. C. (2018). Hydrological Studies for the Assessment of Run-of-River Hydropower Potential and Generation over the Wouri-Nkam River using GIS and Remote Sensing Techniques. Aquademia: Water, Environment and Technology, 2(1), 02.

28 Lin, Z., & Qi, J. (2019). A new remote sensing approach to enrich hydropower dams' information and assess their impact distances: A case study in the Mekong River Basin. Remote Sensing, 11(24), 3016.

29 Tian, Y., Zhang, F., Yuan, Z., Che, Z., & Zafetti, N. (2020). Assessment power generation potential of small hydropower plants using GIS software. Energy Reports, 6, 13931404-.

30 Aqua~Media International (2023), World Atlas of Hydropower and Dams, Available online: https://www.hydropower-dams.com/product/2022-world-atlas-industry-guide/ (accessed on 2 March, 2024).

31 Bharti, A., Paritosh, K., Mandla, V. R., Chawade, A., & Vivekanand, V. (2021). Gis application for the estimation of bioenergy potential from agriculture residues: An overview. Energies, 14(4), 898.

32 Zhang, B., Yang, J., & Cao, Y. (2021). Assessing Potential Bioenergy Production on Urban Marginal Land in 20 Major Cities of China by the Use of Multi-View High-Resolution Remote Sensing Data. Sustainability, 13(13), 7291.

33 Manolis, E. N., Zagas, T. D., Karetsos, G. K., & Poravou, S. A. (2018). Spatial limitations in forest biomass harvesting using Geographic Information System and Remote Sensing for an ecological and sustainable bioenergy framework. Journal of Sustainable Forestry, 37(7), 712726-.

34 Van Holsbeeck, S., & Srivastava, S. K. (2020). Feasibility of locating biomass-to-bioenergy conversion facilities using spatial information technologies: A case study on forest biomass in Queensland, Australia. Biomass and Bioenergy, 139, 105620.

35 Bharti, A., Paritosh, K., Mandla, V. R., Chawade, A., & Vivekanand, V. (2021). GIS Application for the Estimation of Bioenergy Potential from Agriculture Residues: An Overview. Energies 2021, 14, 898.

36 Longato, D., Gaglio, M., Boschetti, M., & Gissi, E. (2019). Bioenergy and ecosystem services trade-offs and synergies in marginal agricultural lands: A remote-sensing-based assessment method. Journal of Cleaner Production, 237, 117672.

37 Zhang, J., Li, J., Dong, C., Zhang, X., Rentizelas, A., & Shen, D. (2021). Comprehensive assessment of sustainable potential of agricultural residues for bioenergy based on geographical information system: A case study of China. Renewable Energy, 173, 466478-.

38 Lak Kamari, M., Isvand, H., & Alhuyi Nazari, M. (2020). Applications of multi-criteria decision-making (MCDM) methods in renewable energy development: A review. Renewable Energy Research and Applications, 1(1), 4754-.

39 Abdi, A., Astaraei, F. R., & Rajabi, N. (2024). GIS-AHP-GAMS based analysis of wind and solar energy integration for addressing energy shortage in industries: A case study. Renewable Energy, 225, 120295.

40 Yousefi, H., Moradi, S., Zahedi, R., & Ranjbar, Z. (2024). Developed analytic hierarchy process and multi criteria decision support system for wind farm site selection using GIS: A regional-scale application with environmental responsibility. Energy Conversion and Management: X, 100594.

41 Rekik, S., & El Alimi, S. (2024). A spatial perspective on renewable energy optimization: Case study of southern Tunisia Using GIS and multicriteria decision making. Energy Exploration & Exploitation, 42(1), 265291-.

43 Hassan, Q., Al-Musawi, T. J., Algburi, S., Al-Razgan, M., Awwad, E. M., Viktor, P.,... & Salman, H. M. (2024). Evaluating energy, economic, and environmental aspects of solar-wind-biomass systems to identify optimal locations in Iraq: A GIS-based case study. Energy for Sustainable Development, 79, 101386.

44 Sapkota, K., Shabbiruddin, & Sherpa, K. S. (2024). Wind farm site suitability assessment & validation using geospatially explicit multi-criteria approach: A case study of South Sikkim, India. International Journal of Green Energy, 21(2), 300327-.

45 Yildiz, S. S. (2024). Spatial multi-criteria decision-making approach for wind farm site selection: A case study in Balıkesir, Turkey. Renewable and Sustainable Energy Reviews, 192, 114158.

46 Sachit, M. S., Shafri, H. Z. M., Abdullah, A. F., Rafie, A. S. M., & Gibril, M. B. A. (2024). A novel GeoAI-based multidisciplinary model for SpatioTemporal Decision-Making of utility-scale wind–solar installations: To promote green infrastructure in Iraq. The Egyptian Journal of Remote Sensing and Space Sciences, 27(1), 120136-.

47 Ferreira, M. M., Santos, J. A., da Silva, L. R., Abrahao, R., Gomes, F. D. S. V., & Braz, H. D. M. (2023). A new index to evaluate renewable energy potential: A case study on solar, wind and hybrid generation in Northeast Brazil. Renewable Energy, 217, 119182.

48 Alotaibi, O. S., & Anzah, F. (2023). Applying an AHP–GIS model to hybrid wind–solar energy site selection in a hot desert region: A case study of the Kuwaiti desert. Geografisk Tidsskrift-Danish Journal of Geography, 123(1), 2541-.

49 Aghaloo, K., Ali, T., Chiu, Y. R., & Sharifi, A. (2023). Optimal site selection for the solar-wind hybrid renewable energy systems in Bangladesh using an integrated GIS-based BWM-fuzzy logic method. Energy Conversion and Management, 283, 116899.

50 Samak, Y. A. A. (2023). Geospatial multi-criteria analysis for solar and wind power modelling for Kingdom of Saudi Arabia's population using GIS: A case study for the cities of Makkah and Jeddah. American Journal of Geographic Information System, 12(1), 2842-.

51 Alhammad, A., Sun, Q., & Tao, Y. (2022). Optimal solar plant site identification using GIS and remote sensing: framework and case study. Energies, 15(1), 312.

52 Gerbo, A., Suryabhagavan, K. V., & Kumar Raghuvanshi, T. (2022). GIS-based approach for modeling grid-connected solar power potential sites: a case study of East Shewa Zone, Ethiopia. Geology, Ecology, and Landscapes, 6(3), 159173-.

53 Effat, H. A., & El-Zeiny, A. M. (2022). Geospatial modeling for selection of optimum sites for hybrid solar-wind energy in Assiut Governorate, Egypt. The Egyptian Journal of Remote Sensing and Space Science, 25(2), 627637-.

54 Hazaymeh, K., Zeitoun, M., Al-Rawabdeh, A., & Al-Sababhah, N. (2018). A regional scale photovoltaic site selection based on geospatial techniques. Jordan Journal of Earth and Environmental Sciences, 9(1), 4756-.

55 Nanaki, E. A., & Xydis, G. A. (2018). Deployment of renewable energy systems: barriers, challenges, and opportunities. Advances in renewable energies and power technologies, 207229-.

56 Resch, B., Sagl, G., Törnros, T., Bachmaier, A., Eggers, J. B., Herkel, S.,... & Gündra, H. (2014). GIS-based planning and modeling for renewable energy: Challenges and future research avenues. ISPRS International Journal of Geo-Information, 3(2), 662-692.

57 Jahangiri, M., Ghaderi, R., Haghani, A., & Nematollahi, O. (2016). Finding the best locations for establishment of solar-wind power stations in Middle-East using GIS: A review. Renewable and Sustainable Energy Reviews, 66, 3852-.

58 Firozjaei, M. K., Nematollahi, O., Mijani, N., Shorabeh, S. N., Firozjaei, H. K., & Toomanian, A. (2019). An integrated GIS-based Ordered Weighted Averaging analysis for solar energy evaluation in Iran: Current conditions and future planning. Renewable Energy, 136, 11301146-.

59 Stoof, C. R., Richards, B. K., Woodbury, P. B., Fabio, E. S., Brumbach, A. R., Cherney, J.,... & Steenhuis, T. S. (2015). Untapped potential: opportunities and challenges for sustainable bioenergy production from marginal lands in the Northeast USA. BioEnergy Research, 8, 482501-.

60 Costa, F. R., Ribeiro, C. A. A. S., Marcatti, G. E., Lorenzon, A. S., Teixeira, T. R., Domingues, G. F.,... & de Carvalho, J. R. (2020). GIS applied to location of bioenergy plants in tropical agricultural areas. Renewable energy, 153, 911918-.

61 Shao, M., Han, Z., Sun, J., Xiao, C., Zhang, S., & Zhao, Y. (2020). A review of multi-criteria decision making applications for renewable energy site selection. Renewable Energy, 157, 377403-.

62 Roa, H. N., Loza-Aguirre, E., & Flores, P. (2019, April). A survey on the problems affecting the development of open government data initiatives. In 2019 sixth international conference on edemocracy & egovernment (icedeg) (pp. 157163-). IEEE.

63 Sengupta, M., Xie, Y., Lopez, A., Habte, A., Maclaurin, G., & Shelby, J. (2018). The national solar radiation data base (NSRDB). Renewable and sustainable energy reviews, 89, 5160-.

64 Sah, D. K., & Amgoth, T. (2020). Renewable energy harvesting schemes in wireless sensor networks: A survey. Information Fusion, 63, 223247-.

65 Breyer, C., Bogdanov, D., Aghahosseini, A., Gulagi, A., Child, M., Oyewo, A. S.,... & Vainikka, P. (2018). Solar photovoltaics demand for the global energy transition in the power sector. Progress in Photovoltaics: Research and Applications, 26(8), 505523-.

66 Alhamwi, A., Medjroubi, W., Vogt, T., & Agert, C. (2019). Development of a GIS-based platform for the allocation and optimisation of distributed storage in urban energy systems. Applied Energy, 251, 113360.

67 Machete, R., Falcão, A. P., Gomes, M. G., & Rodrigues, A. M. (2018). The use of 3D GIS to analyse the influence of urban context on buildings' solar energy potential. Energy and Buildings, 177, 290302-.

References

- Abdi, A., Astaraei, F. R., & Rajabi, N. (2024). GIS-AHP-GAMS based analysis of wind and solar energy integration for addressing energy shortage in industries: A case study. Renewable Energy, 225, 120295.
- Aghaloo, K., Ali, T., Chiu, Y. R., & Sharifi, A. (2023). Optimal site selection for the solar-wind hybrid renewable energy systems in Bangladesh using an integrated GIS-based BWM-fuzzy logic method. Energy Conversion and Management, 283, 116899.
- Alhammad, A., Sun, Q., & Tao, Y. (2022). Optimal solar plant site identification using GIS and remote sensing: framework and case study. Energies, 15(1), 312.
- Alhamwi, A., Medjroubi, W., Vogt, T., & Agert, C. (2019). Development of a GIS-based platform for the allocation and optimisation of distributed storage in urban energy systems. Applied Energy, 251, 113360.
- Alotaibi, O. S., & Anzah, F. (2023). Applying an AHP–GIS model to hybrid wind–solar energy site selection in a hot desert region: A case study of the Kuwaiti desert. Geografisk Tidsskrift-Danish Journal of Geography, 123(1), 2541-.
- Andrade, A. M. D., Michel, R. F. M., Bremer, U. F., Schaefer, C. E. G. R., & Simões, J. C. (2018). Relationship between solar radiation and surface distribution of vegetation in Fildes Peninsula and Ardley Island, Maritime Antarctica. International Journal of Remote Sensing, 39(8), 22382254-.
- Aqua~Media International (2023), World Atlas of Hydropower and Dams, Available online: https://www.hydropower-dams.com/product/2022-world-atlas-industry-guide/ (accessed on 2 March, 2024).

- Avtar, R., Sahu, N., Aggarwal, A. K., Chakraborty, S., Kharrazi, A., Yunus, A. P.,... & Kurniawan, T. A. (2019). Exploring renewable energy resources using remote sensing and GIS—A review. Resources, 8(3), 149.
- Bellaoui, M., Bouchouicha, K., & Oulimar, I. (2021). Estimation of daily global solar radiation based on MODIS satellite measurements: The case study of Adrar region (Algeria). Measurement, 183, 109802.
- Bharti, A., Paritosh, K., Mandla, V. R., Chawade, A., & Vivekanand, V. (2021). Gis application for the estimation of bioenergy potential from agriculture residues: An overview. Energies, 14(4), 898.
- Breyer, C., Bogdanov, D., Aghahosseini, A., Gulagi, A., Child, M., Oyewo, A. S.,... & Vainikka, P. (2018). Solar photovoltaics demand for the global energy transition in the power sector. Progress in Photovoltaics: Research and Applications, 26(8), 505523-.
- Cevallos-Sierra, J., & Ramos-Martin, J. (2018). Spatial assessment of the potential of renewable energy: The case of Ecuador. Renewable and Sustainable Energy Reviews, 81, 11541165-.
- Chaurasiya, P. K., Azad, A. K., Warudkar, V., & Ahmed, S. (2021). Advancement in remote sensing of wind energy. In Advances in Clean Energy Technologies (pp. 207233-). Academic Press.
- Choi, Y., Suh, J., & Kim, S. M. (2019). GIS-based solar radiation mapping, site evaluation, and potential assessment: A review. Applied Sciences, 9(9), 1960.
- Costa, F. R., Ribeiro, C. A. A. S., Marcatti, G. E., Lorenzon, A. S., Teixeira, T. R., Domingues, G. F.,... & de Carvalho, J. R. (2020). GIS applied to location of bioenergy plants in tropical agricultural areas. Renewable energy, 153, 911918-.
- Effat, H. A., & El-Zeiny, A. M. (2022). Geospatial modeling for selection of optimum sites for hybrid solar-wind energy in Assiut Governorate, Egypt. The Egyptian Journal of Remote Sensing and Space Science, 25(2), 627637-.
- Elkadeem, M. R., Younes, A., Sharshir, S. W., Campana, P. E., & Wang, S. (2021). Sustainable siting and design optimization of hybrid renewable energy system: A geospatial multi-criteria analysis. Applied Energy, 295, 117071.
- Fallahi, S., Amanollahi, J., Tzanis, C. G., & Ramli, M. F. (2018). Estimating solar radiation using NOAA/AVHRR and ground measurement data. Atmospheric Research, 199, 93102-.
- Fasipe, O. A., Izinyon, O. C., & Ehiorobo, J. O. (2021). Hydropower potential assessment using spatial technology and hydrological modelling in Nigeria river basin. Renewable Energy, 178, 960976-.
- Ferreira, M. M., Santos, J. A., da Silva, L. R., Abrahao, R., Gomes, F. D. S. V., & Braz, H. D. M. (2023). A new index to evaluate renewable energy potential: A case study on solar, wind and hybrid generation in Northeast Brazil. Renewable Energy, 217, 119182.
- Firozjaei, M. K., Nematollahi, O., Mijani, N., Shorabeh, S. N., Firozjaei, H. K., & Toomanian, A. (2019). An integrated GIS-based Ordered Weighted Averaging analysis for solar energy evaluation in Iran: Current conditions and future planning. Renewable Energy, 136, 11301146-.
- Gerbo, A., Suryabhagavan, K. V., & Kumar Raghuvanshi, T. (2022). GIS-based approach for modeling grid-connected solar power potential sites: a case study of East Shewa Zone, Ethiopia. Geology, Ecology, and Landscapes, 6(3), 159173-.

- Groppi, D., de Santoli, L., Cumo, F., & Garcia, D. A. (2018). A GIS-based model to assess buildings energy consumption and usable solar energy potential in urban areas. Sustainable cities and society, 40, 546558-.
- Hassan, Q., Al-Musawi, T. J., Algburi, S., Al-Razgan, M., Awwad, E. M., Viktor, P.,... & Salman, H. M. (2024). Evaluating energy, economic, and environmental aspects of solar-wind-biomass systems to identify optimal locations in Iraq: A GIS-based case study. Energy for Sustainable Development, 79, 101386.
- Hazaymeh, K., Zeitoun, M., Al-Rawabdeh, A., & Al-Sababhah, N. (2018). A regional scale photovoltaic site selection based on geospatial techniques. Jordan Journal of Earth and Environmental Sciences, 9(1), 4756-.
- Hazaymeh, K., Zeitoun, M., Al-Rawabdeh, A., & Al-Sababhah, N. (2018). A regional scale photovoltaic site selection based on geospatial techniques. Jordan Journal of Earth and Environmental Sciences, 9(1), 4756-.
- He, Y. L., Wang, K., Qiu, Y., Du, B. C., Liang, Q., & Du, S. (2019). Review of the solar flux distribution in concentrated solar power: non-uniform features, challenges, and solutions. Applied Thermal Engineering, 149, 448474-.
- Jahangiri, M., Ghaderi, R., Haghani, A., & Nematollahi, O. (2016). Finding the best locations for establishment of solar-wind power stations in Middle-East using GIS: A review. Renewable and Sustainable Energy Reviews, 66, 3852-.
- Kariuki, B. W., & Sato, T. (2018). Interannual and spatial variability of solar radiation energy potential in Kenya using Meteosat satellite. Renewable energy, 116, 8896-.
- Khan, K. S., & Tariq, M. (2018). Wind resource assessment using SODAR and meteorological mast–A case study of Pakistan. Renewable and Sustainable Energy Reviews, 81, 24432449-.
- Lak Kamari, M., Isvand, H., & Alhuyi Nazari, M. (2020). Applications of multi-criteria decision-making (MCDM) methods in renewable energy development: A review. Renewable Energy Research and Applications, 1(1), 4754-.
- Liang, J., Gong, J., Xie, X., & Sun, J. (2020). Solar3D: A 3D Extension of GRASS GIS r. sun for Estimating Solar Radiation in Urban Environments.
- Lin, Z., & Qi, J. (2019). A new remote sensing approach to enrich hydropower dams' information and assess their impact distances: A case study in the Mekong River Basin. Remote Sensing, 11(24), 3016.
- Longato, D., Gaglio, M., Boschetti, M., & Gissi, E. (2019). Bioenergy and ecosystem services trade-offs and synergies in marginal agricultural lands: A remote-sensing-based assessment method. Journal of Cleaner Production, 237, 117672.
- Machete, R., Falcão, A. P., Gomes, M. G., & Rodrigues, A. M. (2018). The use of 3D GIS to analyse the influence of urban context on buildings' solar energy potential. Energy and Buildings, 177, 290302-.
- Manolis, E. N., Zagas, T. D., Karetsos, G. K., & Poravou, S. A. (2018). Spatial limitations in forest biomass harvesting using Geographic Information System and Remote Sensing for an ecological and sustainable bioenergy framework. Journal of Sustainable Forestry, 37(7), 712726-.
- Masoom, A., Kosmopoulos, P., Bansal, A., & Kazadzis, S. (2020). Solar energy estimations in india using remote sensing technologies and validation with sun photometers in urban areas. Remote Sensing, 12(2), 254.

- Mishra, T., Rabha, A., Kumar, U., Arunachalam, K., & Sridhar, V. (2020). Assessment of solar power potential in a hill state of India using remote sensing and Geographic Information System. Remote Sensing Applications: Society and Environment, 19, 100370.
- Nanaki, E. A., & Xydis, G. A. (2018). Deployment of renewable energy systems: barriers, challenges, and opportunities. Advances in renewable energies and power technologies, 207229-.
- Qazi, A., Hussain, F., Rahim, N. A., Hardaker, G., Alghazzawi, D., Shaban, K., & Haruna, K. (2019). Towards sustainable energy: a systematic review of renewable energy sources, technologies, and public opinions. IEEE access, 7, 6383763851-.
- Rahman, M. M., & Zhang, W. (2019). Review on estimation methods of the Earth's surface energy balance components from ground and satellite measurements. Journal of Earth System Science, 128, 122-.
- Rekik, S., & El Alimi, S. (2024). A spatial perspective on renewable energy optimization: Case study of southern Tunisia Using GIS and multicriteria decision making. Energy Exploration & Exploitation, 42(1), 265291-.
- Resch, B., Sagl, G., Törnros, T., Bachmaier, A., Eggers, J. B., Herkel, S.,... & Gündra, H. (2014). GIS-based planning and modeling for renewable energy: Challenges and future research avenues. ISPRS International Journal of Geo-Information, 3(2), 662692-.
- Roa, H. N., Loza-Aguirre, E., & Flores, P. (2019, April). A survey on the problems affecting the development of open government data initiatives. In 2019 sixth international conference on edemocracy & egovernment (icedeg) (pp. 157163-). IEEE.
- Sachit, M. S., Shafri, H. Z. M., Abdullah, A. F., Rafie, A. S. M., & Gibril, M. B. A. (2024). A novel GeoAI-based multidisciplinary model for SpatioTemporal Decision-Making of utility-scale wind–solar installations: To promote green infrastructure in Iraq. The Egyptian Journal of Remote Sensing and Space Sciences, 27(1), 120136-.
- Sah, D. K., & Amgoth, T. (2020). Renewable energy harvesting schemes in wireless sensor networks: A survey. Information Fusion, 63, 223247-.
- Samak, Y. A. A. (2023). Geospatial multi-criteria analysis for solar and wind power modelling for Kingdom of Saudi Arabia's population using GIS: A case study for the cities of Makkah and Jeddah. American Journal of Geographic Information System, 12(1), 2842-.
- Sapkota, K., Shabbiruddin, & Sherpa, K. S. (2024). Wind farm site suitability assessment & validation using geospatially explicit multi-criteria approach: A case study of South Sikkim, India. International Journal of Green Energy, 21(2), 300-327.
- Sengupta, M., Xie, Y., Lopez, A., Habte, A., Maclaurin, G., & Shelby, J. (2018). The national solar radiation data base (NSRDB). Renewable and sustainable energy reviews, 89, 5160-.
- Shao, M., Han, Z., Sun, J., Xiao, C., Zhang, S., & Zhao, Y. (2020). A review of multi-criteria decision making applications for renewable energy site selection. Renewable Energy, 157, 377403-.

- Siddiqui, A., Joshi, D. K., Rehman, S., Kumar, P., & Devadas, V. (2020). A solar intensive approach for smart environment planning in Gandhinagar, Gujarat. Smart Environment for Smart Cities, 197238-.
- Stoof, C. R., Richards, B. K., Woodbury, P. B., Fabio, E. S., Brumbach, A. R., Cherney, J.,... & Steenhuis, T. S. (2015). Untapped potential: opportunities and challenges for sustainable bioenergy production from marginal lands in the Northeast USA. BioEnergy Research, 8, 482501-.
- Tian, Y., Zhang, F., Yuan, Z., Che, Z., & Zafetti, N. (2020). Assessment power generation potential of small hydropower plants using GIS software. Energy Reports, 6, 13931404-.
- Torres Junior, A. R., Saraiva, N. P., Assireu, A. T., Neto, F. L., Pimenta, F. M., de Freitas, R. M.,... & Oliveira, D. Q. (2022). Performance Evaluation of LIDAR and SODAR Wind Profilers on the Brazilian Equatorial Margin. Sustainability, 14(21), 14654.
- Van Holsbeeck, S., & Srivastava, S. K. (2020). Feasibility of locating biomass-to-bioenergy conversion facilities using spatial information technologies: A case study on forest biomass in Queensland, Australia. Biomass and Bioenergy, 139, 105620.
- WEC (World Energy Council) 2024, World Energy Resources, Available online: https://www.iea.org/energy-system/renewables/hydroelectricity#tracking (accessed on 2 March, 2024).
- Yevalla, G. M. S., Seidou, D. N., Ngoc, B. V., Hoi, T. V., & Tabod, T. C. (2018). Hydrological Studies for the Assessment of Run-of-River Hydropower Potential and Generation over the Wouri-Nkam River using GIS and Remote Sensing Techniques. Aquademia: Water, Environment and Technology, 2(1), 02.
- Yildiz, S. S. (2024). Spatial multi-criteria decision-making approach for wind farm site selection: A case study in Balıkesir, Turkey. Renewable and Sustainable Energy Reviews, 192, 114158.
- Yousefi, H., Moradi, S., Zahedi, R., & Ranjbar, Z. (2024). Developed analytic hierarchy process and multi criteria decision support system for wind farm site selection using GIS: A regional-scale application with environmental responsibility. Energy Conversion and Management: X, 100594.
- Zhang, B., Yang, J., & Cao, Y. (2021). Assessing Potential Bioenergy Production on Urban Marginal Land in 20 Major Cities of China by the Use of Multi-View High-Resolution Remote Sensing Data. Sustainability, 13(13), 7291.
- Zhang, J., Li, J., Dong, C., Zhang, X., Rentizelas, A., & Shen, D. (2021). Comprehensive assessment of sustainable potential of agricultural residues for bioenergy based on geographical information system: A case study of China. Renewable Energy, 173, 466478-.
- Zhu, L., Suomalainen, J., Liu, J., Hyyppä, J., Kaartinen, H., & Haggren, H. (2018). A review: Remote sensing sensors. Multi-purposeful application of geospatial data, 1942-.
- Østergaard, P. A., Duic, N., Noorollahi, Y., & Kalogirou, S. (2022). Renewable energy for sustainable development. Renewable Energy, 199, 11451152-.
- Capareda, S. (2019). Introduction to renewable energy conversions. CRC Press.

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