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Review Article

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Reviews on Remote Sensing and GIS of Biomass-Based Renewable Energy

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ABSTRACT

Remote sensing and geographical information systems (GIS) are vital tools that can be used to capture the spatial and temporal dynamics of biomass energy. They can be used alone or integrated with other software tools to improve biomass energy security at the strategic and military science levels. There has been a lot of development in the research and application of GIS in biomass and energy assessment globally. This is why spatial and temporal waste or biomass data are not readily available in these areas. Despite the advancements in remote sensing and GIS technologies, there are several challenges, such as the need for improved data availability, especially in regions where spatial and temporal waste or biomass statistics are limited, and the need for technical expertise and interoperability. These challenges need to be overcome in order to utilize these tools for biomass-based renewable energy. This paper reviews recent developments in the application of remote sensing and GIS in biomass and energy security, with the objective of designing biomass energy systems that support green and clean economies globally. The paper also discusses the challenges associated with the use of these tools and the contributions that have been made to address these challenges.

Keywords: *Remote Sensing, Renewable Energy, Biomass Energy, Green Economy, Sustainable Energy, Waste Management*

INTRODUCTION

Remote sensing is the art and science of acquiring information about some property of an object, area, or phenomenon which is not in physical contact with the objects or area under investigation [30] [48] [4]. The instruments employed for this reason may utilize any of an assortment of physical energy dispersions. For example, sonars deal with the principle of acoustic wave propagation, while optical instruments, such as the photographic camera and multispectral scanner, utilize electromagnetic energy conveyance. By doing so, the interactions of electromagnetic radiation with the Earth's surface measured by airborne or space-borne sensors are used to collect data of interest in a given area and search data at fixed intervals to reveal changes in the land-use/land-cover patterns [48]. The science of remote sensing includes a wide range of technologies and techniques. The present study has focused on information collected from aerial platforms, although ground-oriented sensors also hold potential for energy-related assessments in rural environments. A rural energy system describes the integration of energy demand, supply, and distribution in rural areas. This study was planned to examine the role of remote sensing in each of these rural energy system components. Specifically, the relevant fundamental physical or statistical energy-modelling principles were considered about remote sensing inputs. This study suggested that active remote sensing technologies offer substantial prospects for informing a wide range of assessments of rural energy.

Remote sensing technologies offer a generous ability to illuminate each of these components. Historically, aerial photography has been the primary technology used by rural management and development practitioners due to technical constraints. However, technological advances and the increasing accessibility of high spatial resolution passive and active remote sensing technologies are enabling a wealth of novel rural functions. The effective rural energy management and planning process is the spatial demonstration of supply resources, the requirement for energy services, and the fundamental physical infrastructure and land use patterns that facilitate the connection between energy demand and supply [28]. However, rising opportunities for small-scale distributed energy production technologies within villages, the promotion of building energy efficiency, and support for community energy systems have improved the function and responsibility of local governments and organizations in energy-related management and planning [17][35][36].

An energy system represents the holistic process of acquiring and using energy in a society or economy [29]. Traditionally, rural areas have been associated with the demand-side of energy systems, resulting from their substantial requirements for energy services and the physical and social constraints. The accurate surface temperature dimensions from thermal sensors must be corrected for atmospheric absorption and emission effects, in addition to surface emissivity and the anisotropic effects of surface geometric structure [75]. Consequently, the structural representation of the rural surface therefore, remains a key factor for evaluating environmental circumstances.

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Physical models of energy demand for space conditioning can be informed in part by building volume and interactions with the outdoor setting [52].

Rural electrification is a catalyst for improving agricultural productivity, poverty alleviation, and rural development. Also solar home systems are feasible for rural electrification and that a combination of short, medium and long-term strategies can help policymakers plan and execute sustainable rural electrification projects [33]. The relationship between access to electricity and socio-economic advancement in rural areas of developing countries was revealed and was developed in an energy-economic model to analyze the possibility of electrification and to estimate socio-economic conditions through the dissemination of electric lighting appliances. They also applied multiple regression analysis. Together with other socio-economic factors, this could contribute to poverty eradication and lead developing countries toward sustainable development [34].

A case study was conducted in Chhattisgarh, India, to assess the effects of village electrification through solar power on beneficiaries and whether technical and maintenance factors met the desired results set by Indian rural electrification policy. In villages where the systems had been installed in the past two years, children studied an average of 41 minutes more in the evenings, more than twice as much as before electrification. Dinner cooking commenced on average 36 minutes later, a sign of increased flexibility in time use and women's empowerment. Furthermore, the median household monthly kerosene use decreased by 2 liters or 67%, but commercial productive activities were limited. Seventy-five percent of the 69 micro-grid power plants evaluated were found to have too little output to supply the stated 6 hours of daily light per household, and the capacity installed per household decreased with village size. Plant capacity factors were found to vary greatly, most likely due to poor installation and/or inferior components [47].

In many developing countries, the national electricity grid fails to provide rural communities with a reliable supply of electricity. The three approaches to the relationship between grid and off-grid electrification were: separated, uncoordinated, and integrated. Explicit integration is the most effective approach because it prevents duplication of effort. Explicit policy integration is necessary to encourage investment in off-grid electrification and to avoid leaving the poorest and geographically most remote segments of the rural population without access to electricity [73].

1. Remote Sensing and GIS of Renewable Energy

The government's renewable energy programs aim to improve people's quality of life and reduce the existing pressure on natural resources. They criticize participatory approaches for planning and implementation in the rural energy sector, and express the need for a decentralized participatory process that includes institutional support for sustainable and equitable management of rural energy sources.

Optimization modelling is an efficient way to integrate renewable energy systems. The model provides least-cost system design and operation, considering hour-by-hour energy availability and demand [51]. Rural electrification alone is unlikely to solve the energy access problem because of low penetration of electricity in the energy mix of the poor after energy access situation in India whereas long-term strategies would be required to integrate developmental efforts with energy access issues to create opportunities for higher income generation and to make energy supply affordable through judicious use of alternative instruments [6].

Selection of renewable sources for power generation can be stated as an optimization problem and will be useful for planning to meet the peak load demand at the regional level. The proposed linear programming methodology provides an easy tool for the solution of selecting the optimal mix of renewable energy sources. A computational result indicates that the power generated by renewable resources is quite suitable to meet the peak load demand, and in fact, some regions have the potential to transfer power to other regions using the existing transmission line network [18].

The actual demand for coal, oil, and electricity has been predicted using the MEM model out of three energy models: the Modified Econometric Mathematical (MEM) model, the Mathematical Programming Energy-Economy-Environment (MPEEE) model, and the Optimal Renewable Energy Mathematical (OREM) model, based on economic, technological, and environmental factors. The results were used in the MPEEE model, which determines the optimum allocation of commercial energy sources based on environmental limitations. The gap between the real energy requirement from the MEM model and optimal energy exploitation from the MPEEE model has to be met by means of renewable energy sources. They also developed an OREM model that would facilitate effective utilization of renewable energy sources in India, based on cost, efficiency, social acceptance, reliability, potential, and demand. The financial variations in solar energy systems and consideration of environmental limitations are also examined with the OREM model. The OREM model will help policy makers in the planning and execution of strategies concerning sustainable energy sources in India for the next 20 years. The objective of the model is to minimize the cost/efficiency ratio subject to social acceptance, reliability, demand, and potential constraints using the Delphi technique [27].

In a hybrid energy system in the form of an object structure there is the pattern for the structure of options in the evaluation of a hybrid system. The object structure is defined as a hybrid energy system produced by solar, wind, biomass, natural gas, and utilized for electricity, heat, and hydrogen. They also stated that the multi-criteria method has the potential for the determination of the Sustainability Index rating. In the evaluation of quality of the selected hybrid systems, they selected several options to demonstrate the sustainability assessment methods in the promotion of the specific quality of the hybrid energy system [1].

On investigated it was founded that India's reliance has exacerbated the problem of high carbon dioxide (CO_2) emissions from the combustion of fossil fuels, primarily coal, in the country's energy sector. It was also founded on analysing that thermal power generation in India for a four-year period and determined the net generation from thermal power stations, the total and specific CO_2 emissions, and identified and compared the installed generating capacity, net generation, CO_2 emissions figures, large generators, large emitters, and fuel types. It was also founded that Indian coal-fired thermal power plants operate at an efficiency below 30% [21].

Renewable energy technologies (RETs) was recognized as one of the most important ways to beautify the rural ecological environment, enrich the energy supply of rural households, and reduce the financial burden of rural dwellers from commercial energy consumption in China. It was also reported that the key factors affecting the adoption and popularization of RETs in rural construction in China are initial investment, subsidies, financial support, technical service support, and communication [81].

A hybrid renewable energy system can be used to reduce dependency on either conventional energy or renewable energy systems. Optimization of hybrid renewable energy systems involves the process of selecting the best components and sizing them with an appropriate operation strategy to provide cheap, efficient, reliable, and cost-effective alternative energy. A methodology was developed for optimum planning of a hybrid PV-Wind system with some battery backup and analyzed local solar radiation, wind data, and component data from different manufacturers and simulated the system in HOMER to assess the technical and economic viability of the integrated system. They evaluated the performance of each component and performed sensitivity analysis to optimize the system at different conditions. They concluded that economic viability should be in top priority over technical feasibility for rural electrification in countries like India, where end consumers have limited financial resources [20].

In a simplified model for optimization of a small, hybrid, decentralized power plant that takes into account wind, solar, and biomass resources at a location and determines how these three energy sources can be best pooled into a hybrid system to meet the load demand. The tool, called HYPORA (Hybrid Power Optimized for Rural/Remote Areas), takes into account not only the scientific basis of renewable energy, but also economic and demand factors, including government incentives. It is based on the Microsoft Excel platform and can be used by engineers and scientists, as well as the general public, policymakers, investors, and students, due to its user-friendliness [56].

While studying the governance of clean energy in India in order to improve understanding of the potential and limitations of carbon finance in supporting lower carbon energy transitions and the role of politics in enabling or frustrating such endeavors, the importance of politics and the nature of India's political economy in understanding the progress of sources of energy and technologies defined as "clean" by the United Nations Clean Development Mechanism (CDM). They also suggested that India's early state-led growth in clean energy technologies has largely dictated the role that the CDM has played in the country [55].

While studying the energy requirements in India it was founded that energy requirements are steadily increasing and that the requirement is being met by both commercial and renewable energy sources. However, due to the non-availability of adequate resources and the large amount of emission of pollutants from commercial energy, it is now being felt that renewable energy has to be exploited to a larger extent. They found that a 3% increase in social acceptance of bio resources was accompanied by a 65% decrease in solar PV utilization [70].

2. Remote Sensing and GIS of Forest Biomass Resources

Remote sensing relies on the measurement of electromagnetic energy reflected or emitted by the earth's surface [30] [78]. Electromagnetic energy, which propagates through space in the form of waves, is characterized by electrical and magnetic fields that are perpendicular to each other [78]. The absence of reliable information and sound assessment methods in ecological studies can have the most profound consequences for the conservation of biodiversity and for the identification of indicator species that can predict changes in a given ecosystem. Data for these purposes could be acquired using both ground-based and remote sensing methods [62].

Ground-based methods of data acquisition include field observations, collection of in-situ data and measurements, and land surveying activities. Remote sensing methods are based on the use of image data acquired by sensors of different types, such as aerial cameras, scanners, or radar. Satellite remote sensing is a timely technological development in view of serious pressures on our natural habitat [59]. It is used to interpret the images or numerical values obtained from a distance in order to acquire meaningful information of particular features on Earth [31][45]. For the last couple of decades, the application of remote sensing has not only revolutionized the way data have been collected, but also significantly improved the quality and accessibility of important spatial information for the conservation and management of natural resources. The parallel advance in the reliability of GIS has permitted the interpretation of large quantities of data generated through remote sensing to address different environmental problems [4].

Remote sensing data are being used to manage various types of natural resources and to monitor the dynamics of land use/land cover, which is a basic prerequisite for planning and implementing various developmental activities. They further described that the vegetation analysis of a given area using remote sensing depends on the interactions of the plant with incoming solar radiation. For any surface that light strikes, there are three forms of interaction: absorption, transmission, and reflection. The proportions of each of these interactions depend on the wavelength of the light and the material and condition of the feature. However, the spectral properties of vegetation in different parts of the spectrum can be interpreted to reveal information about the health and status of forests and other types of Earth features [50].

Plants can be distinguished from other terrestrial surfaces by their specific absorption and reflection patterns. Specifically, plants absorb red and blue wavelengths of light and reflect green and infrared wavelengths. This absorption characteristic is dependent upon the physiological status of the plant and may be considered as a measure of greenness. Other land-based surface features exhibit different light absorption and reflection patterns and can therefore be easily distinguished from vegetative land cover [46].

The vegetation index is used to quantify the vegetation cover on the surface of the Earth. Regardless of the different types of vegetation indices, the Normalized Difference Vegetative Index (NDVI) is the most widely used in studying the health of the ecosystem in general [23] [41]. NDVI is a ratio index that exploits the high reflectance of plant biomass in the near-infrared (NIR) region compared to the fairly low reflectance in the red (R) region of the electromagnetic spectrum. It is an indicator of the greenness of vegetation canopies by which vegetation characteristics can be detected from other land surface features. Its ratio represents the fractional difference due to the absorption of red light by chlorophyll from the total of near-infrared and red light being reflected from the surface of vegetative structures.

The applications of remote sensing and GIS technologies in nature conservation ranges from simple tasks such as determining the location of sampling sites, plotting maps, or examining the distribution of soil types in relation to yields and productivity, to more complex tasks such as vegetation classification for predicting crop yield or environmental impacts, modelling of surface water drainage patterns or animal migration patterns. Biomass energy supplies comprise a wide range of resources and technologies [46]. High spatial resolution remote sensing products offer potential to inform rural biomass estimates. Forest structure attributes, such as canopy height derived from LiDAR data, have been used to develop allometric relationships with biophysical parameters such as volume and above-ground biomass [79].

On identification of the problems of fuel insufficiency, over-exploitation of biomass resources, poor reliability, and quality of energy services available to the rural masses of India. The renewable energy programs of the government aimed to improve the people's quality of life and reduce the existing pressure on natural resources. Participatory approaches for planning and implementation in the rural energy sector was criticised and expressed the need for a decentralized participatory process that includes institutional support for sustainable and equitable management of rural energy sources [11].

On working in implications of remote sensing in forests and for ecosystem services comparing three models for mapping abandoned plots using Sentinel-2 with 10 m bands, Sentinel-2 with 10 m and 20 m bands, and airborne imagery with 1 m visible and near-infrared bands using pixel-based classification approach for the Random Forests algorithm. The algorithm was trained with 144 plots and 100 decision trees. The results were confirmed using the hold-out method with 96 independent plots. The most accurate map was found using airborne images, the Enhanced Vegetation Index (EVI) and Thiam's Transformed Vegetation Index (TTVI), with 88.5% accuracy [49].

Remote sensing offers important insights into pressing environmental challenges and is a critical tool for driving solutions. The use of remote sensing in forest ecology and management, which includes mapping forest resources and differentiating the three-dimensional structure of forests using different sensors such as multispectral and synthetic aperture radar, and platforms such as unmanned aerial vehicles and satellites was found significant and it can be concluded that remote sensing technology can support forest management and conservation for many vital environmental issues [40].

3. Remote Sensing and GIS of Agriculture

During the initial stages of satellite remote sensing, analysts primarily focused on using data to classify land cover types, with crop types being a significant area of interest for agricultural applications. In recent years, the focus in agricultural remote sensing has shifted towards characterizing plant biophysical properties. Remote sensing has long been used for monitoring and analyzing agricultural activities. Remote sensing of agricultural canopies has provided valuable insights into various agronomic parameters [14]

The advantage of remote sensing lies in its ability to provide repeated information without destructive sampling of the crop, which is useful for precision agricultural applications. Remote sensing offers a cost-effective alternative to data acquisition over large geographical areas. Additionally, Satellite remote sensing is mainly used for crop acreage and production estimation in India [43]. Remote sensing technology can alter the location and characterization of agricultural productivity based on biophysical traits of crops and soils. Data collected by remote sensing satellites can be used for yield estimation, crop phenological information, and detection of stress situations and disturbances [19] [61] [22] [5].

The combination of remote sensing and GIS application for creating spatio- temporal informative layers can be successfully applied to diverse fields including floodplain mapping, hydrological modeling, surface energy flux, rural development, land use changes, crop growth monitoring, and stress detection [37]. The advancements in remote sensing methods can be attributed to the introduction of narrow-band or hyperspectral sensors and increased spatial resolution of satellite-mounted sensors. Hyperspectral remote sensing has improved the detailed analysis of crop characterization. Hyperspectral sensors (ranging from 400 to 2500 nm) was comprehensively examined for crop classification using data mining methods such as principal components analysis, lambda–lambda models, stepwise discriminant analysis, and vegetation indices [71]. Numerous studies have involved various types of sensors that can provide reliable data at a fraction of the cost of traditional data gathering methods.

On assessing the current status of advanced farm management to help farmers save money while protecting the environment and transforming sustainable food production to meet the growing population's needs. It was also emphasized that regular information about farms leads to optimal decision-making. Digital solutions, combined with robotics and artificial intelligence, are revolutionizing agriculture through Agriculture 5.0 platforms for every farm [60]. However, on investigating the challenges of mapping winter wheat using Sentinel-2 and Landsat-8 data it was explored that the potential of combining temporally aggregated Landsat-8 OLI and Sentinel-2 MSI data on the Google Earth Engine platform for mapping winter wheat in Shandong Province, China. Their study highlighted the importance of data from specific winter wheat growth stages, such as maturing and reviving stages, for accurate classification [80].

Remote sensing plays a crucial role in agriculture by providing timely spectral information for assessing the biophysical indicators of plant health. It was also explained that the physiological changes in plants due to stress can alter their spectral reflectance/emission characteristics, allowing for the detection of stress using remote sensing techniques [44]. Monitoring crop growth at regular intervals is essential for taking appropriate measures and predicting potential production losses due to stress factors. Crop yield depends on various factors such as crop variety, water and nutrient status of the field, weed, pest and disease infestation, and weather conditions. The spectral response curve is influenced by these factors, and changes in the curve indicate the yield condition and performance. Utilizing satellites like IRS P3 WiFS, IRS-1C WiFS, and LISS3, which have good periodicity, can enable the generation of growth profiles and retrieval of yield-related parameters at the regional level.

Similarly, It was also explained that crop growth stages and development are influenced by factors such as soil moisture availability, planting date, air temperature, day length, and soil condition. These factors affect plant conditions and productivity [53]. For example, high temperatures during corn pollination can negatively impact corn crop yields. Knowing the temperature at the time of corn pollination can help forecasters better predict yields.

Later it was described that drought renders land unsuitable for cultivation and creates an inhospitable environment for human beings, livestock, biomass potential, and plant species. Satellite-based drought monitoring has gained acceptance in recent years, with the use of the Normalized Difference Vegetation

Index (NDVI) and Vegetation Condition Index (VCI) for identifying agricultural drought in different regions with varying environmental conditions [67]. Moreover, It was highlighted that the use of various vegetation indices such as reflectance ratio, NDVI, PVI, transformed vegetation index, and greenness index for characterizing crop growth and condition. Operational remote sensing utilizes annual NDVI profiles to extract twelve Vegetation Phenology Metrics (VPMs), which are used to characterize agricultural vegetation response to climate and land management practices [57].

Remote sensing and GIS are particularly valuable in nutrient and water stress management. Detecting nutrient stresses through remote sensing and GIS enables site-specific nutrient management, reducing cultivation costs and increasing fertilizer use efficiency for crops. In semi-arid and arid regions, precision farming technologies enable judicious water use. For instance, combining drip irrigation with remote sensing data, such as temperature contrasts, can improve water use efficiency by reducing losses through runoff and infiltration. Stressed crops exhibit higher spectral reflectance in the visible region compared to non-stressed crops. Vegetation indices such as NDVI, RVI, PVI, and GI are lower for stressed crops and higher for non-stressed crops [13]. The use of microwave remote sensing for estimating soil moisture availability in the field was also highlighted [3]. Remote sensing data can provide information on crop water demand, water use, soil moisture conditions, and related crop growth stages. For example, NOAA satellite data was used to assess the performance and presence of three major irrigation projects in Sri Lanka. Remote sensing was used to compare crop-water consumption with available water to determine irrigation efficiency.

High-Resolution Land Data Assimilation System (HRLDAS) was used to develop a soil moisture and temperature map for India. This system provides soil moisture and temperature data at a spatial resolution of 1 km in near real-time, enabling accurate and timely monitoring of these parameters [13]. Remote sensing, particularly with the advancement of hyperspectral bands, has become increasingly important in understanding soil attributes and improving precision farming. Combining remote sensing data with GPS technology can yield promising results, enhancing the accuracy of agricultural practices.

In wet tropical and subtropical climates, the risk of nitrogen leaching is high due to the spatial variability of soil properties, such as soil organic matter content and water content. This variability affects the nitrogen status of crops, leading to the inefficiency of conventional single-rate nitrogen application. Variable-rate nitrogen fertilization based on yield sensors has been proposed as a solution to improve nitrogen application efficiency. Remote sensing has also been used to estimate crop yields by establishing statistical relationships between yield and vegetation indices.

Accurate information on crop production before harvest is crucial for national food policy planning. Remote sensing has the potential to support adaptive agricultural practices by providing reliable crop status information throughout the growing season. It can be applied in various agricultural activities such as crop breeding, land use monitoring, crop yield estimation, and environmental services related to soil, water resources, and biodiversity conservation.

The importance of remote sensing as a valuable tool for timely and accurate monitoring of the agricultural sector and with high revisit frequency and accuracy, remote sensing, along with other advanced technologies like GPS and GIS, plays a significant role in the assessment and management of agricultural activities [65]. To achieve sustainable agricultural management, it is essential to analyze the various factors influencing the agricultural sector on a spatiotemporal basis.

4. Remote Sensing and GIS in Livestock Management

Livestock production in the developing world encompasses a wide range of heterogeneous systems. These include pastoral/grassland-based systems with low human population densities, mixed crop-livestock systems in areas suitable for both production and where the majority of rural population resides, and intensive systems found mainly in rural areas. Additionally, landless systems are prevalent in urban areas to meet the high demand for meat, milk, lamb, pork, and poultry globally [24].

The importance of these systems is expected to grow as future livestock production growth is projected to occur primarily in the developing world [8][58]. Mixed systems currently contribute the majority of meat and milk in developing countries [64] [69] [24] and also play a crucial role in global food security, accounting for nearly 50% of the global cereal output [24] [25].

However, the most significant rates of increase in animal production, both observed in recent decades and projected for the future, are in the intensive pig and poultry sectors of the developing world [15] [8] [67]. Livestock assets are valuable possessions for rural households, serving as collateral and facilitating access to credit and financial services while also enhancing social status [66] [9].

Efficient management of waste biomass in logistics and supply chains is critical. Stakeholders involved in the planning and execution of waste biomass supply chains face a multitude of decisions at different levels of the decision-making process. A taxonomy of research efforts related to waste biomass supply chains has been developed to provide a comprehensive overview of the field [26].

Livestock farms generate manure that poses a high risk of pollution. Traditional disposal methods, such as direct use as fertilizers, can lead to environmental problems such as odor and pollution. Environmentally sustainable alternatives, including large-scale biomass-to-energy schemes, offer potential economic benefits and often produce plant food as a by-product. Resource mapping and analysis play a crucial role in identifying viable sources of collectible yard manure for biomass-to-energy plants. Tools like remote sensing and GIS are particularly useful for renewable energy applications, as geographical location strongly influences resource availability (e.g., farm livestock manures) and the ability to access and utilize it. Various factors, such as the location of the resource, physical and practical constraints, environmental and regulatory restrictions, and economic considerations, must be carefully considered [12].

Scope of Work

The study explore the various remote sensing and GIS technologies available for capturing the spatial and temporal dynamics of biomass-based waste for energy. This include satellite imagery, aerial surveys, and data analysis techniques. The research focus on the application of remote sensing and GIS in biomass and energy assessment at different scales, ranging from local to global. This may involve mapping biomass resources, monitoring changes in biomass distribution and availability over time, and quantifying biomass potential for energy generation. The study can examine contribution of remote sensing to energy planning and security. This involve using biomass and energy assessment data to inform strategic decision-making processes, such as identifying suitable locations for biomass-to-energy facilities and optimizing energy production and distribution systems. The study highlight the role of remote sensing and GIS in supporting green and clean economies. This include assessing the environmental impacts of biomass-based energy systems, evaluating the sustainability of biomass resource utilization, and identifying opportunities for renewable energy integration within existing energy infrastructure. Further the study discusses the challenges associated with utilizing remote sensing and GIS in biomass and energy assessment, such as data availability, technical expertise, and interoperability. Additionally, it highlight the contributions made to address these challenges, such as improving data collection methods, developing standardized protocols, and promoting capacity building initiatives. Overall, the scope of the study would encompass the application of remote sensing and GIS technologies in biomass-based renewable energy assessment, energy planning, and supporting sustainable and environmentally friendly economies.

Summary and Conclusions

The present study illustrated that the energy demand pattern and potential availability of local bio-resource through remote sensing and GIS technology was very useful for analyzing the energy gap at the micro as well as macro scale.

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Conflict of Interest

Not Applicable

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