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https://doi.org/10.5109/7323295

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 10, pp.419-426, 2024-10-17. International Exchange and Innovation Conference on Engineering & Sciences
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Renewable Energy Resource Assessment for Agusan Del Norte, Caraga Region, Philippines

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Abstract: *This study assessed the solar and biomass energy resources in Agusan del Norte, Caraga region, Philippines. Using r.sun in GRASS GIS, solar energy potential was calculated. Biomass potential and suitable sites for solar PV farms and biomass power plants were identified via Weighted Multi-Criteria Analysis in QGIS. The assessment used available data, including SRTM DEM, slope and aspect layers, Julian date, declination, and LandSAT biomass potential. The r.sun data showed clear seasonal irradiance patterns, with peak global horizontal irradiance (GHI) in June and the lowest in December. Magallanes had the highest annual mean GHI, followed by Butuan City. The province's theoretical biomass potential was 47,762.35 MT residue/year, with Butuan City having the highest at 18,767 MT residue/year. Butuan was identified as the most suitable for solar PV farms, confirmed by a 10 MW solar project. It also has significant potential for biomass power from rice husks, evidenced by a 47 MW biomass power plant under construction. Future studies should explore additional data for improved accuracy.*

Keywords: energy resource assessment, solar, biomass, multi-criteria decision analysis, QGIS

1. INTRODUCTION

Energy is a crucial driver of economic and societal growth, with biomass energy being a significant source globally. The utilization of energy fosters job creation, agricultural productivity, industrialization, transportation, and trade expansion, ultimately leading to poverty alleviation and sustainable human development. Energy is vital not only for developing a nation's economy but also for enhancing human well-being [1].

The pressing need to switch from fossil fuels to renewable energy sources has gained worldwide attention in recent years. Environmental concerns, energy security, and economic advantages are a few of the elements influencing the global transition to sustainable energy systems [2]. The province of Agusan del Norte, which is situated in the northeastern part of the Philippine Island of Mindanao, is at a crossroads where the assessment and use of renewable energy sources are essential for sustainable growth. Agusan del Norte is endowed with various natural resources that may be used to generate renewable energy thus is poised to have plenty of renewable energy resource potential [3]. To realize their full potential, these resources must be thoroughly assessed, evaluated for feasibility, and suitable locations for renewable energy projects identified.

Moreover, like many other regions in the Philippines, Agusan del Norte is largely reliant on traditional energy sources, notably fossil fuels. The province's existing energy mix is dominated by coal and oil, making it sensitive to fluctuations in worldwide oil prices and exposing the environment to damaging pollutants [4]. Recognizing the limitations of traditional energy, there is a growing push to investigate and accept renewable energy solutions.

The urgent need to mitigate the negative effects of climate change is one of the key reasons for considering renewable energy in Agusan del Norte. As an archipelago, the Philippines is particularly vulnerable to the consequences of global warming, such as increasing sea levels, increased frequency of extreme weather events, and ecological degradation [5]. Agusan del Norte can dramatically lower its carbon footprint, cut greenhouse gas emissions, and contribute to global efforts to battle climate change by switching to renewable energy sources.

Renewable energy assessment in Agusan del Norte has enormous potential for improving the province's energy security and self-sufficiency [6]. Currently, the province is reliant on imported fossil fuels, making it vulnerable to geopolitical threats and price volatility [7]. Investing in renewable energy infrastructure, such as solar and biomass power, would diversify the energy mix while decreasing reliance on foreign sources. This diversification would also promote energy resilience and stability, providing a continuous and inexpensive supply of energy for the province's industries, enterprises, and communities.

This study focuses on the assessment of renewable energy sources for Agusan del Norte, Caraga Region. The study investigates the solar and biomass potential of the province and identifies suitable sites for ground mounted solar photovoltaic cells and biomass energy facilities. Moreover, the study investigates the potential environmental and social impacts of these renewable energy sources

2. MATERIALS AND METHODS

This study aims to evaluate and recommend a suitable renewable energy supply for Agusan del Norte province in the Philippines by conducting an energy resource assessment. The assessment follows a general workflow depicted in Figure 1. Once the target site is determined, relevant data is collected from journals and published documents from private and government organizations. These data are then analyzed to provide an evaluation of different renewable energy opportunities available in the selected location. Importantly, the assessment process considers the existing energy system of the site and utilizes the available natural resources to develop an integrated energy system that optimizes the province's potential. Quantum GIS (QGIS) software is to be employed during the analysis and selection process.

To evaluate the feasibility and potential of an energy production site, energy resource assessment involves a series of key steps. The initial stage involves site selection, where factors such as geographical features, proximity to transmission infrastructure, and accessibility are considered to identify suitable locations for energy development.

Fig. 1. General energy resource assessment workflow

Once a site is chosen, the assessment proceeds to evaluate the energy supply characteristics of the area. This includes analyzing existing energy infrastructure, available resources, and energy demand patterns to determine the energy requirements and potential sources. Another critical step is the assessment of renewable energy potential, which plays a crucial role in evaluating the viability of clean energy utilization.

This assessment entails analyzing the availability of renewable resources in the selected location. Parameters such as solar irradiance and biomass potential are carefully evaluated to gauge the renewable energy potential of the site. Following the assessment of renewable energy potential, a site suitability analysis is conducted to ascertain the compatibility of the chosen site with the proposed energy project. This analysis considers environmental, technical, social, and economic factors. Impact analysis is an integral part of the energy resource assessment process. It involves evaluating the potential environmental, social, and economic impacts of the proposed energy project. Environmental impacts encompass factors such as habitat disturbance, carbon emissions, or water usage, while social impacts can involve community displacement or changes in local livelihoods. Economic impacts assess the potential benefits of the project, including job creation and economic growth. The final step in the energy resource assessment is validation, wherein the findings and conclusions of the assessment are thoroughly reviewed and verified. This often involves seeking expert opinions and consultation with related literature. The validation process ensures the accuracy and reliability of the assessment results, providing a solid foundation for decision-making regarding energy project implementation.

2.1 Solar resource assessment method

Figure 2 illustrates the resource assessment method employed for solar energy. The assessment utilized a 5-meter resolution Interferometric Synthetic Aperture Radar - Digital Elevation Model (IfSAR DEM) spatial data. This data was processed through the r.slope.aspect algorithm to generate raster layers representing aspect (direction the slope faces) and slope (steepness of the terrain). The aspect and slope raster layers were subsequently employed in conjunction with non-spatial data, namely Julian data (day of the year) and declination (angle between the sun and the Earth's equatorial plane), within the r.sun process.

By integrating these datasets, a comprehensive evaluation of solar resource availability was achieved. The result of this assessment was the generation of a global horizontal irradiance (GHI) raster layer. The GHI raster layer provides information about the amount of solar energy that reaches a horizontal surface at the specified location.

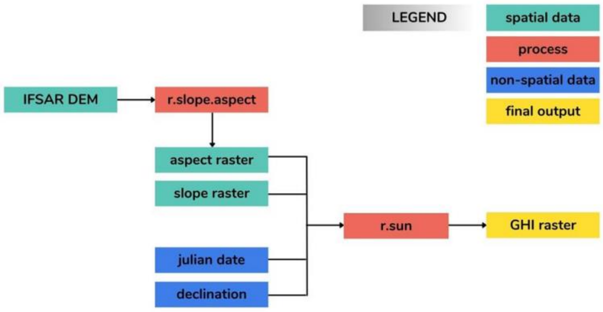

Fig. 2. Solar energy resource assessment process

This data is valuable for estimating solar energy potential and identifying suitable areas for solar energy installations.

2.3 Biomass resource assessment method

In biomass resource assessment, the theoretical and available potential were retrieved using Phil-LiDAR 2 REMap Data Layers. However, since the only available biomass for Agusan del Norte was rice, investigation of the suitability of other crops in the area was also investigated. Crop growth suitability maps for coconut, dry corn, and also rice was investigated by Project SARAi of the Department of Science and Technology (DOST) and the University of the Philippines Los Baños (UPLB). The total annual production of residues for Agusan del Norte was calculated from the equation:

$$B_n = \sum_n A_n Y_n \qquad B_{th} = \sum_n B_n \qquad (1)$$

where for crop n, B is the biomass theoretical potential (MT residue/year), A_n is cultivated area (hectares), Y_n is residue yield (MT/ha/yr), and B_{th} is the total biomass theoretical potential (MT residue/year).

2.4 Solar Annual Energy Potential

To determine the annual energy production potential for various municipalities and cities in the province, the method proposed by Zhang et al. was adopted in this study. Equation 2 represents the formula utilized to calculate the annual energy potential:

$$E = A * r * H * PR \qquad (2)$$

where:

A represents the total area covered by solar panels (in square meters).

r denotes the efficiency of the solar panels (as a percentage).

H signifies the annual average solar radiation received per unit horizontal area (measured in watthours per square meter per year).

PR refers to the performance ratio, a coefficient accounting for energy losses, typically ranging between 0.5 and 0.9.

E represents the annual energy potential (measured in kilowatt-hours per year)

In this study, the calculation of the total solar panel area relied upon the available land area deemed suitable for solar energy development. Equation 3 outlines the procedure for computing the available land area, taking into consideration restricted areas such as protected and built-up zones based on the land cover map data.

2.5 Biomass Annual Energy Potential

The annual energy potential or available potential from biomass considering competing uses and inefficiencies in the collection of residues was calculated based on the Phil-LiDAR 2 REMap Data Layers using the equation:

$$B_{av} = \frac{\sum_n B_n f_g a_n LHV_n}{A_r} \tag{4}$$

where B_{av} is the biomass available potential (kJ/ha/yr), B_n is the biomass theoretical potential (MT/yr), f_g is the efficiency of biomass collection (%), a_n is the availability of biomass for energy production, LHV_n is the lower heating value of the residue from crop (kJ/kg), and A_r is the area of the region under consideration (ha).

2.6 Site suitability

In assessing site suitability, the criteria were derived from the research conducted by Pintor et al. [2] and were categorized into factors and constraints. Factors were assigned weights and, upon standardization, were given values ranging from 0 to 1. Conversely, constraints were employed to filter potential areas and were assigned binary values of 0 or 1. The weights also used in this study were derived from the work of Pintor et al. [2], which employed the Analytical Hierarchical Process (AHP) methodology, ensuring consistency with criteria that have comparable effects on site suitability. The AHP method facilitated a systematic and structured approach to assigning weights to the criteria, ensuring consistency and a rigorous analysis of their relative importance. By utilizing the AHP, the study aimed to establish a well-founded and objective basis for weighting the criteria and ultimately assessing site suitability.

Table 1. Hierarchy of Criteria (Factors)

Level 0	**Suitability**		
Level 1	Resource	Non-Resource	
Level 1	Annual Mean GHI Biomass Potential	Physical	Risk
Level 2		Slope Aspect Land Cover Proximity to water bodies	Flood hazard Flood inundation at 0.5

Furthermore, it is worth noting that the Level 2 criteria, as presented in Table I, which focuses solely on the physical and risk factors, underwent modification due to the limited availability of maps necessary for considering environmental and socio-economic criteria. This alteration is distinct from the approach outlined in the paper by Pintor et al. [2], which includes environmental and socio-economic criteria as part of the Level 2 assessment.

To maintain a rigorous analysis within the given limitations, the scope of the study was narrowed to concentrate on the physical and risk criteria. The aim was to derive meaningful insights into site suitability for solar PV installations, primarily considering factors such as slope, aspect, land use, proximity to water sources, flood hazard, and flood inundation at 0.5 meters.

The site suitability analysis was carried out using the weighted multi-criteria analysis (WMCA) plug-in of QGIS. At the first level of the hierarchy, the criteria were divided into two main groups: resource and non-resource criteria. The non-resource criteria were further classified into two subgroups: Physical and Risk.

The physical criteria addressed the influence of physical characteristics on site suitability, encompassing factors such as the slope and aspect of the area, land use, and proximity to water sources. Flat areas with a southern orientation were preferred, as they required fewer earthworks for the installation of ground-mounted solar photovoltaic (PV) systems. Additionally, open and barren areas were favored over heavily forested regions.

Lastly, proximity to a water source was considered crucial for ensuring a steady water supply to the solar PV plant. The risk criteria, on the other hand, considered the impact of flood hazards and flood inundation at 0.5 meters on the suitability of a site.

2.7 Site information

Agusan del Norte is a province in the Philippines located in the Caraga region (Region XIII), on Mindanao's northeastern coast. It has a land area of 3,428.25 square kilometers which is equivalent to 1,323.65 square miles [5]. Also, the province has 10 municipalities and 2 cities. The total number of barangays in the province is 212. The City of Butuan is commonly grouped with the province, although it is administratively independent due to its being classified as a highly urbanized city [3].

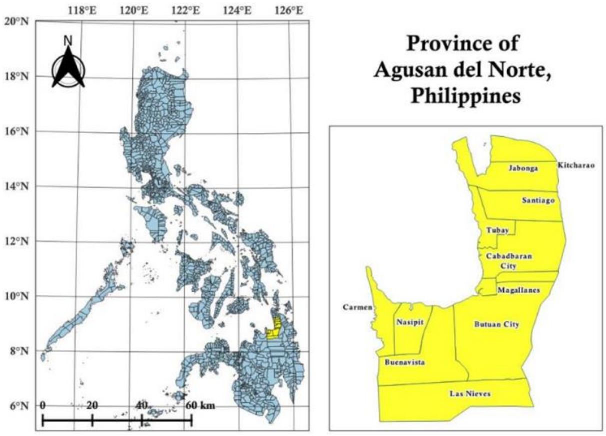

Fig. 3. Project site of the study - Agusan del Norte.

The province is bordered by mountains, the largest of which is Mt. Hilong-Hilong, and is made primarily of low rolling terrain. The elevation is 2,012 meters above sea level. This highland is in the municipality of Remedios T. Romualdez in the province's northeastern corner [6].

Agusan del Norte province in the Philippines showcases a diverse range of land use and cover types that contribute to its distinctive landscape. The province is characterized by a combination of natural and human-made features, each occupying a specific portion of its total land area. Among the different land use and cover categories, annual crops cover 8.538% of the province, representing areas dedicated to cultivating crops that are typically planted and harvested within a year.

Brush and shrubs account for 15.826% of the land area, signifying regions covered by dense vegetation consisting of shrubs, small trees, and thickets.

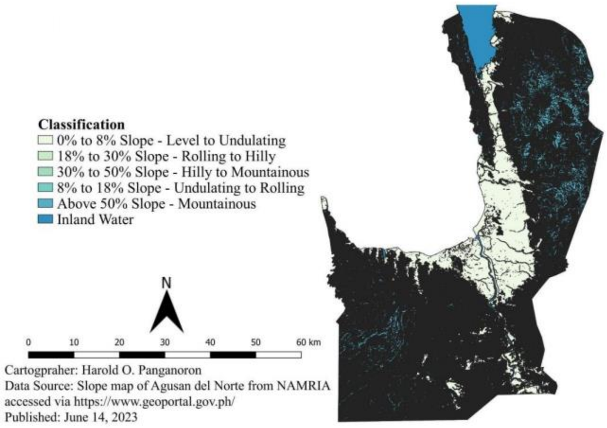

Fig. 4. Slope map of Agusan del Norte.

Built-up areas, comprising residential, commercial, and industrial developments, make up 2.910% of the province's land. Closed forests, accounting for 1.834% of the area, encompass regions with dense tree canopies, indicating the presence of mature or primary forests with limited human disturbance.

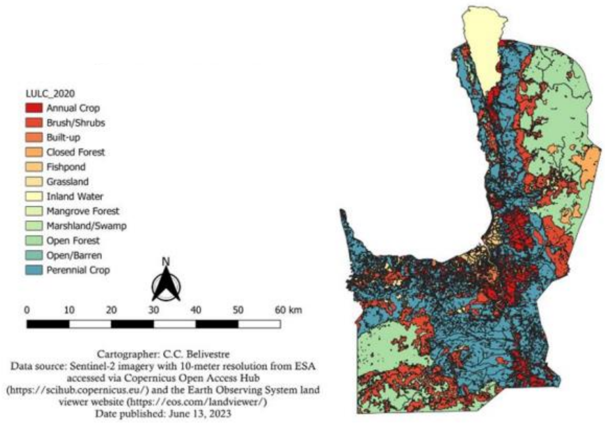

Fig. 5. Land use and cover map of Agusan del Norte.

2.8 Socio-Economic Conditions

The province's economy is mostly agricultural, with rice, corn, coconut, abaca, banana, and mango as key crops. Cassava, durian, pineapple, coffee, vegetables, and root crops are also grown in the province. Coconut, banana, and rice are the three most productive crops, with respective outputs of 75,184.35 MT, 43,924.92 MT, and 26,151.81 MT [17].

2.9 Current Energy Supply Characteristics

The Agusan del Norte Electric Cooperative, Inc. (ANECO) manages the supply and distribution of energy in Agusan del Norte. It is an electric cooperative that distributes power to homes, businesses, and industries. It is a non-stock, non-profit organization [18].

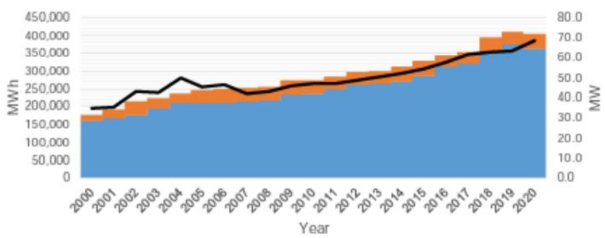

Fig. 6 Historical consumption of Agusan del Norte [18].

Figure 6 illustrates the historical consumption of Agusan del Norte. The demand rose by 8% from 63.15 MW in 2019 to 68.41 MW in 2020. From 418,284 MWh in 2019 to 412,327 MWh in 2020, MWh Offtake marginally declined by 1%.

Within the franchise region, this is considered a consequence of the epidemic. The load factor varied from 74% to 67% throughout the same time period.

As a result of the pandemic, consumption significantly changed in 2020, particularly for commercial and industrial loads. Another consequence of the pandemic is that, while MWh System Loss increased by 2% over the same time period, MWh Output declined by 4% from 2019 to 2020 [18].

Agusan del Norte province has a well-established energy supply infrastructure with several substations serving its distribution network as presented in Figure 7.

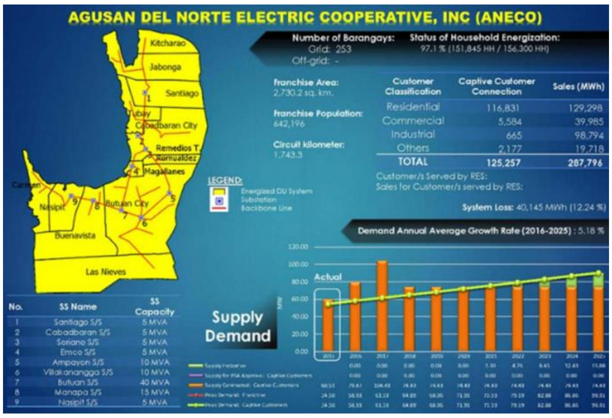

Fig. 7. Energy supply of the province (Department of Energy, n.d.)

The substations in the province, namely Santiago, Cabadbaran, Soriano, Emco, Ampayon, Villa Kananga, Butuan, Manapa, and Nasipit, have capacities ranging from 5 MVA to 40 MVA.

These substations play a crucial role in ensuring a reliable supply of electricity to the consumers. Agusan del Norte's franchise area spans 2,730.2 square kilometers, serving a population of approximately 642,196 people. The circuit kilometer, measuring 1,743.3 circuit kilometers, reflects the extent of the distribution infrastructure required to cater to the province's energy needs.

2.10 Justification for use of Renewable Energy

Table II depicts that a maximum deficit demand is projected to occur in peak demand periods as stipulated in ANECO's 2026 - 2029 forecast. ANECO has planned to address this through WESM or through a 10 MW genset. ANECO mentioned that it will require a rate intensive Diesel plan for the sudden increase in demand. However, considering this and the projected increase in demand in the succeeding year, ANECO would require a more sustainable energy source. This presents a valuable opportunity for the adoption of renewable energy sources for power generation which also is in line with the directives of the Philippine government.

Table 2. ANECO forecasted deficit demand [7]

Year	Days	Time Projected to Occur	No. of hours	Max. Deficit MW
2026	Monday to Friday	10:01 AM to 12:00 NN	2	8
		1:01 PM to 4:00 PM	3	9
		6:01 PM to 9:00 PM	3	7
	Saturday	1:01 PM to 4.00 PM	3	8
		6:01 PM to 9:00 PM	3	7
	Holidays and Sundays	6:01 PM to 9:00 PM	3	6
2027	Monday to Friday	10:01 AM to 12:00 NN	2	13
		1:01 PM to 4:00 PM	3	14
		6:01 PM to 9:00 PM	3	12
	Saturday	1:01 PM to 4.00 PM	3	13
		6:01 PM to 9:00 PM	3	12
	Holidays and Sundays	6:01 PM to 9:00 PM	3	11
2028	Monday to Friday	10:01 AM to 12:00 NN	2	17
		1:01 PM to 4:00 PM	3	18
		6:01 PM to 9:00 PM	3	16
	Saturday	1:01 PM to 4.00 PM	3	17
		6:01 PM to 9:00 PM	3	16
	Holidays and Sundays	6:01 PM to 9:00 PM	3	15
2029	Monday to Friday	10:01 AM to 12:00 NN	2	21
		1:01 PM to 4:00 PM	3	22
		6:01 PM to 9:00 PM	3	20
	Saturday	1:01 PM to 4.00 PM	3	21
		6:01 PM to 9:00 PM	3	20
	Holidays and Sundays	6:01 PM to 9:00 PM	3	19

3. RESULTS AND DISCUSSIONS

3.1 Solar potential

The monthly mean global horizontal irradiance (GHI) for the province of Agusan del Norte varies throughout the year as depicted in Figure 6.1. Based on the generated data using the r.sun process, there is a clear seasonality pattern in the amount of irradiance. The GHI values start relatively low in January and steadily increase until they reach their peak in June. From June onwards, the values gradually decrease until they reach their lowest point in December. The month with the lowest mean GHI is December, with a value of 4,822.790 Wh/m^2 day. This value is significantly lower than the average of the 12 GHI mean values, which is 6787.944 Wh/m^{2}day. The month with the highest mean GHI is June, with a value of 8,148.531 Wh/m2day. This value is higher than the average of the 12 GHI mean values. The standard deviation of the 12 GHI mean values is 751.317. The standard deviation provides a measure of the variability or dispersion of the data points around the mean. In this case, the relatively high standard deviation suggests that there is significant variability in the monthly mean GHI values throughout the year in Agusan del Norte.

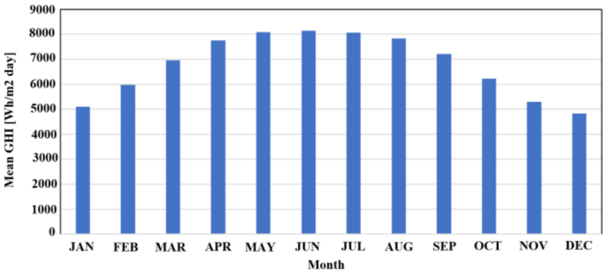

Fig. 8. Monthly mean global horizontal irradiance (GHI)

The seasonality observed in the GHI values indicates that there are distinct periods of higher and lower solar irradiance throughout the year. This information can be used to optimize the design and operation of solar power systems, such as solar panels or solar farms, in Agusan del Norte. Additionally, the low mean GHI value in December suggests that this month might not be as favorable for solar energy generation compared to other months. It could be a period of lower energy production or a time when alternative energy sources need to be considered. On the other hand, the high mean GHI value in June indicates that this month offers the most solar energy potential.

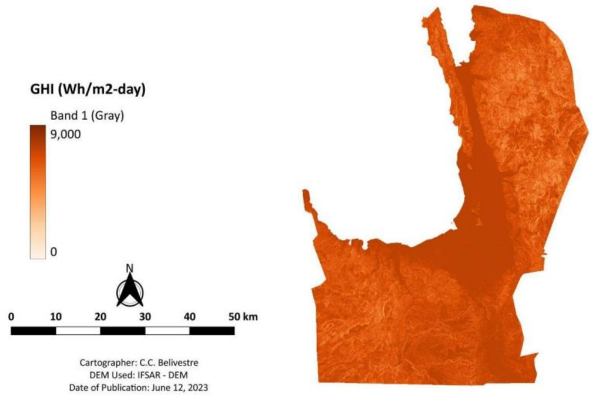

Fig. 9. Annual mean global horizontal irradiance (GHI).

The annual mean global horizontal irradiance (GHI) for various areas in the province of Agusan del Norte is illustrated in Figure 9. GHI represents the total amount of solar radiation received on a horizontal surface. The map reveals the different levels of solar energy potential in each location. Based on the generated data and map, Magallanes has the highest annual mean GHI value of 7,447.181 Wh/m^2-day, indicating it receives the most solar radiation among the municipalities and cities in the province. Following closely is Butuan City with a GHI of

7,164.728 Wh/m^2-day. Las Nieves, Tubay, and Carmen also have relatively high mean GHI values, ranging from 6,990.056 to 6,804.070 Wh/m^2-day. On the other hand, Santiago and Jabonga have the lowest mean GHI values of 6,303.514 and 6,379.197 Wh/m^2-day, respectively. The implications of this data are important for understanding the solar energy potential and planning solar projects in the province.

3.2 Biomass potential

Figure 10 illustrates the theoretical potential for biomass across different cities and municipalities in Agusan del Norte. Overall, Agusan del Norte has a theoretical biomass potential of 47,762.35 MT residue/year. The figure also suggests that Butuan City has the theoretical biomass potential of 18,767 MT residue per year. While all the areas have theoretical potential, the Phil-LiDAR 2 REMap Data Layers has available data only for rice as a potential biomass energy source for Agusan del Norte.

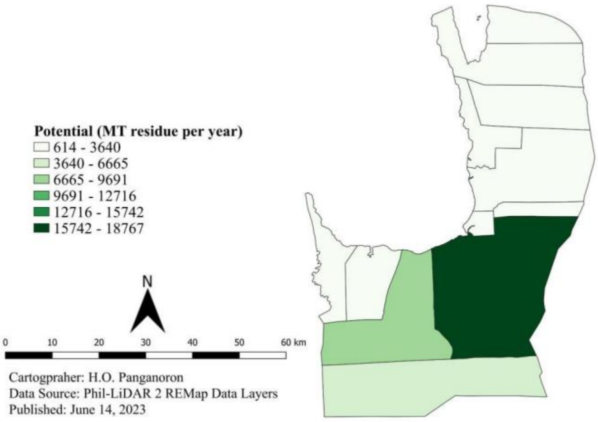

Fig. 10. Theoretical biomass potential for Agusan del Norte.

3.3 Site Suitability

The solar and biomass suitability maps are presented in Figures 11 and 12, respectively. Upon thorough evaluation of the physical criteria, risk criteria, and resource criteria (annual mean GHI), it becomes evident that the ideal location for ground-mounted solar PV farms in Agusan del Norte is limited to Butuan City. Extensive analysis of the physical aspects, including factors like land use and cover, slope, aspect, and proximity to water bodies, reveals that Butuan City offers the most favorable conditions for hosting solar farms. Moreover, when considering the risk criteria, Butuan City stands out as it is relatively shielded from potential hazards such as floods, and inundation, reducing the vulnerability of solar installations. Lastly, the resource criteria, particularly the annual mean GHI (Global Horizontal Irradiance), point to Butuan City as having the second-highest solar energy potential in Agusan del Norte, making it one of the prime choices for harnessing solar power. Taking all these factors into account, Butuan City emerges as the most suitable site for the establishment of ground-mounted solar PV farms in Agusan del Norte. Using similar criteria, biomass suitability was also evaluated, and it was found that a large portion of the suitable site is also located in Butuan City.

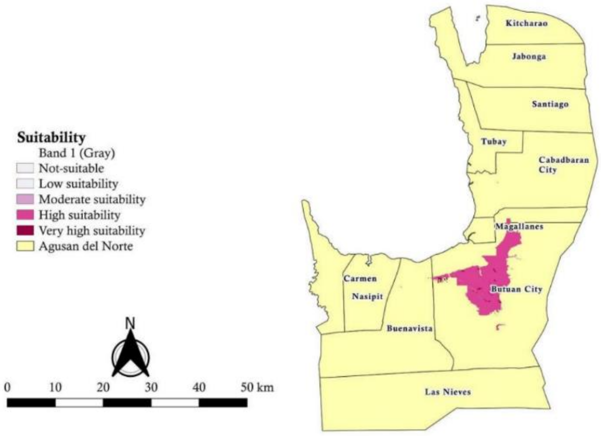

Fig. 11. Site suitability for ground-mounted solar PV farms in Agusan del Norte.

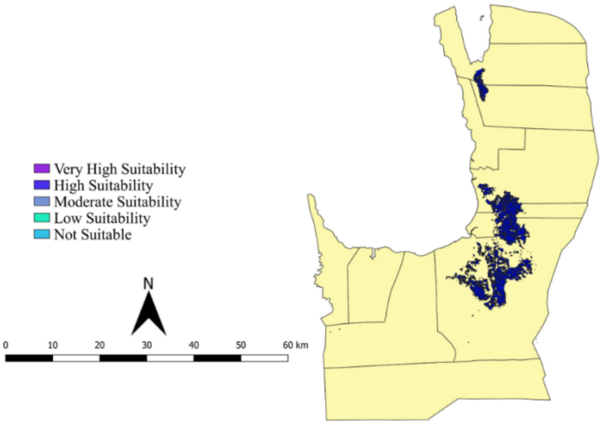

Fig. 12. Site suitability for biomass power plants in Agusan del Norte.

3.4 Availability and Computed Annual Energy Potential (AEP)

To compute and assess the annual energy potential, available areas, and annual solar irradiance, generated QGIS data and formulae were obtained from various literature sources, as described in the Methodology section. The available area was determined by subtracting restricted areas unsuitable for renewable energy development from the total land area of each municipality or city. In the case of annual solar energy potential, all areas except Open/Barren areas were considered restricted. For this study, the total and restricted areas were obtained from the 2020 Land Cover Map for Agusan del Norte. The data was generated through digital interpretation of the Sentinel-2 satellite imagery from the European Space Agency (ESA) with a resolution of 10 meters, covering the period between 2018 and 2019. Additional high-resolution satellite imagery was also used in the analysis. The Sentinel-2 imagery was processed using 12 land cover categories: Closed Forest, Open Forest, Mangrove Forest, Brush/Shrubs, Grassland, Perennial Crop, Annual Crop, Open/Barren, Built-up, Marshland/Swamp, Fishpond, and Inland Water. These categories align with the classification used in the 2015 Land Cover Map. The dataset is referenced based on the Universal Transverse Mercator (UTM) Zone 51N projection, using the Philippine Reference System of 1992 (PRS92) as the horizontal datum. The 2020 Land Cover Map (LCM) of the CARAGA Region was produced by the National Mapping and Resource Information Authority (NAMRIA) as part of its Land Cover Mapping project.

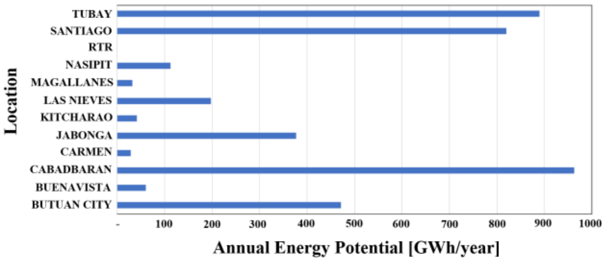

Fig. 13. Annual solar energy potential for Agusan del Norte province.

The results provide an insight into the annual energy potential in Agusan del Norte province, shedding light on key metrics such as total area, available area, and annual mean global horizontal irradiance (GHI). The province's top 6 areas with the highest annual energy potential are as follows: Cabadbaran claims the first position with an impressive annual energy potential of 962 GWh/year, closely trailed by Tubay in second place with 890 GWh/year. Santiago secures the third spot, boasting an energy potential of 820 GWh/year. Butuan City follows suit with an energy potential of 472 GWh/year, ranking fourth, while Jabonga comes in fifth with 377 GWh/year. Las Nieves rounds off the top 6 with an annual energy potential of 198 GWh/year. Conversely, areas with lower annual energy potential, such as RTR, Carmen, and Magallanes, may not be as suitable for large-scale solar energy projects. However, it is important to acknowledge that this analysis solely focuses on solar energy potential, and other renewable energy sources like wind, hydro, or geothermal power may yield different implications for these areas.

3.5 Biomass Energy Potential

Illustrated in Figure 14 is the theoretical potential for biomass based on the Phil-LiDAR 2 REMap Data Layers. Agusan del Norte in total has an available biomass potential of 14,359.30 kJ/ha/year. The figure also shows that Magallanes has a theoretical biomass potential of 2,580.79 kJ/ha/year.

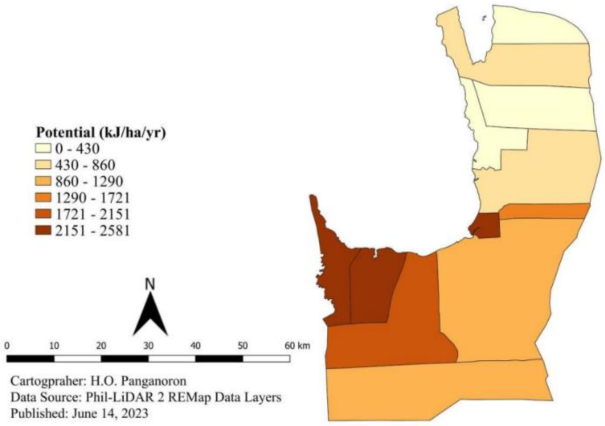

Fig. 14. Available biomass potential for Agusan del Norte.

The available potential, however, shows that municipalities with the highest available potential have lower land area of their respective territory. However, if the available potential is multiplied with the area of the city or municipality, Butuan City would have the highest available potential of 876,151.60 kJ/yr. Considering the available and theoretical energy potential, Butuan City proves to be a favorable location for biomass power generation from rice husks. With its abundant agricultural activities, particularly in rice production, the city possesses a significant amount of rice husks that can be utilized as a renewable energy source.

3.6 Environmental and Social Impacts

Ground-mounted solar PV farms in open or barren areas can have both environmental and social impacts in the province of Agusan del Norte, specifically in Butuan City (based on site suitability analysis). From an environmental perspective, these solar farms can contribute to the reduction of greenhouse gas emissions by generating clean and renewable energy. This helps in mitigating climate change and improving air quality, leading to a healthier environment for both humans and wildlife. In terms of social impacts, the establishment of ground-mounted solar PV farms in Butuan City can bring several benefits to the local community. Firstly, it creates job opportunities during the construction, operation, and maintenance phases of the solar farms. These employment opportunities can stimulate the local economy and provide income for the residents. Furthermore, the development of solar energy infrastructure can attract investments and promote economic growth in the region. Furthermore, the presence of solar PV farms can enhance the energy security of Butuan City by diversifying its energy sources. By reducing dependence on fossil fuels and the grid, solar power can provide a reliable and sustainable energy supply, reducing the risk of power outages and improving energy resilience.

Biomass energy is frequently considered as a viable option for lowering greenhouse gas emissions and attaining sustainable development. Since air emissions and waste generation are potential impacts of biomass energy production, health and well-being is a social impact of biomass energy generation. Workers in the biomass manufacturing and processing industries may suffer occupational health and safety hazards. Dust, allergens, hazardous compounds, and noise exposure during biomass collecting, transportation, and processing can cause respiratory difficulties, skin problems, hearing impairments, and accidents. Preserving the health and well-being of workers in the biomass energy sector, effective safety measures, training, use of protective equipment, and adherence to occupational health rules are critical [17].

4. CONCLUSION

The results of the study indicate that the r.sun tool in GRASS GIS effectively modeled the global horizontal irradiance (GHI) in Agusan del Norte province. To generate GHI raster layers, several essential data inputs are required, including (but not limited to) a high-resolution digital elevation model (DEM), slope raster, aspect raster, Julian date, and declination. These inputs play a crucial role in accurately modeling the global horizontal irradiance (GHI) in a specific area, such as the province of Agusan del Norte. By incorporating these data sets into the analysis, it becomes possible to assess the solar energy potential and identify areas with varying levels of solar radiation, providing valuable insights for solar energy planning and development. The availability of annual mean GHI data provides valuable information on the solar energy potential across the province, enabling the identification of areas with varying solar radiation levels. Furthermore, based on the evaluated resource and non-resource criteria, Butuan City emerges as the most suitable location for ground-mounted solar PV farms in Agusan del Norte. It offers favorable physical conditions, such as land use, slope, aspect, and proximity to water bodies. Additionally, Butuan City is relatively shielded from potential hazards and possesses the second-highest solar energy potential in the province.

Moreover, it was also illustrated that the theoretical and available potential for biomass for Agusan del Norte can be evaluated from the Phil-LiDAR 2 REMap Data Layers. Agusan del Norte has a theoretical biomass potential of 47,762.35 MT residue/year in which Butuan City has potential of 18,767 MT residue/year. This is equivalent to an available biomass potential of 14,395.30 kJ/ha/yr and to 1,072.90 kJ/ha/yr respectively. Further analysis of the suitability of the sites shows Butuan City is a highly suitable area for biomass energy production because of favorable land use, slope, aspect, and proximity to water bodies.

Solar and biomass power projects will contribute significantly to the local energy generation capacity, reducing reliance on conventional energy sources and fostering a more sustainable energy future for Agusan del Norte. However, it is important to consider the various environmental and social impacts of energy production from these sources. Considering the impacts of renewable energy projects on the local community will foster acceptability and sustainability of these renewable energy sources.

Access to sustainable energy is a key driver of economic growth. Access to renewable and modern forms of energy is an "important precondition" for combating energy poverty, promoting economic growth, enhancing employment opportunities, and supporting essential social services [19].

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