Evaluation du potentiel solaire des régions naturelles de la Guinée

Abstract

This article assesses the solar potential of Guinea's four natural regions (Lower Guinea, Middle Guinea, Upper Guinea, and Forest Guinea) based on data from the network of automatic weather stations deployed in 2023 by the National Meteorological Agency (ANM). These stations, equipped with modern sensors, measure key climate parameters (temperature, humidity, wind, solar radiation, precipitation, and pressure). The analysis highlights spatial and seasonal variability in solar radiation : Kankan, Conakry, and Labé have the highest levels of solar radiation, at 230,26 Wh/m², 225,53 Wh/m² and 207,19 Wh/m², reflecting a drier and sunnier climate, while N'zérékoré, which experiences heavy rainfall, records the lowest value (189,18 Wh/m²). The results show that March, April, and November are the most favorable months for photovoltaic production, whereas July and August are limited by cloud cover. Analysis of the hourly and monthly curves of total solar irradiance showed good agreement among the regions studied. Furthermore, this study identified the sunniest regions in Guinea and the most favorable periods for harnessing solar energy. The results of this study can be used to guide investment decisions in Guinea's solar energy sector and contribute to the country's energy transition. The study highlights the importance of extending the observation period (20 to 30 years) to ensure robust validation and proposes, as a future step, the development of a solar potential map covering all prefectures in Guinea and the West African subregion.

Keywords : Assessment, potential, solar, natural regions, Guinea.

I. Introduction

Solar energy is a viable alternative to conventional energy sources because it is clean, quiet, and unlimited compared to conventional energy sources. Therefore, it is essential to encourage the use of solar energy in urban areas to generate clean energy and reduce emissions of greenhouse gases (GHGs) and other pollutants [1].

Understanding solar radiationor solar irradianceat the earth's surface is of great interest in many fields. In the energy sector, the need to reduce greenhouse gas emissions requires the replacement of fossil fuels with renewable energy sources [2], [3].

Research on the assessment of solar potential is being conducted by several researchers in various countries, using a variety of datasets and methods. Some studies use in situ measurements to directly assess irradiance and solar potential, notably in Niger [4], Algeria [5], and India [6].

Others combine in situ measurements with empirical models to validate and refine estimates of solar potential at fine scales, including: [7], [8], [9], [10] in Algeria; [11] in Burkina Faso; [12], [13], [14], [15] in Senegal; Y. Eissa (2015) in Egypt. These models make it possible to estimate solar radiation at the ground level—particularly in regions where direct measurements are scarce—by relying on parameters such as insolation, cloud cover, and elevation. They offer a good balance between accuracy and simplicity, facilitating their application in energy or climate studies.

Empirical models, calibrated at the local or regional level, used to generate solar potential indices based on climatic and radiative variables: [16] in Germany; [17], [18], [19] in Algeria; [20] in Belgium; [21] in Spain. The results show that certain theoretical models accurately reproduce actual values, while also highlighting discrepancies depending on local conditions.

Other studies combine satellite data with in situ measurements to cross-validate the results and improve their robustness: [6] in India; [22] in Europe; [23] in Pakistan; [10] in Algeria. The results indicate that these products are suitable for clean energy applications, providing a reliable estimate of the solar resource needed to design photovoltaic systems. The spatial resolution enables better local energy planning, particularly in rural areas. These data enhance access to scientific information for sustainable development in West Africa.

The combination of empirical models and GIS data, or satellite data and GIS data, to produce more detailed potential maps tailored to local constraints, such as [24] in China; [25] in Vietnam. [26] used GIS data to map solar potential in India, incorporating territorial constraints to facilitate spatial analysis.

In this study, we will use data collected at 15-minute intervals from the network of automatic weather stations deployed in 2023 by the National Meteorological Agency (ANM). Next, we will conduct a comparative study of trends in total solar radiation across Guinea's four natural regions.

II. Methodology

II.1 Overview of the Study Area

The Republic of Guinea is located in the northern tropics, between 7° and 12° north latitude and 7° and 15° west longitude. It has an area of 245,857 km² and an estimated population of 12 million. It is bordered to the north by Senegal and part of Mali, to the east by Mali and Côte d'Ivoire, to the south by Liberia and Sierra Leone, and to the west by Guinea-Bissau and the Atlantic Ocean. Based on its topography and vegetation, Guinea comprises four natural regions (Lower Guinea, Middle Guinea, Upper Guinea, and Forest Guinea), each with distinct climatic characteristics [27].

II.1.1 Lower Guinea or Maritime Guinea:

Located along the Atlantic coast, the region receives very high annual rainfall (more than 3,000 mm on average per year, and more than 4,000 mm in Conakry). The influence of the harmattan is less pronounced here, and relative humidity remains very high, ranging on average between 63 and 94%. Temperatures are also high, with an annual average of 28°C, a high of 32°C in April–May, and a low of 23°C in December[28].

This constant, humid heat is conducive to agriculture and vegetation growth. The vegetation, which is of the tropical coastal type, consists of mangroves in the coastal marshlands, palm and coconut trees, open forests, and wooded savannas[28].

II.1.2 Middle Guinea or Fouta Djallon:

The climate of Foutan, influenced by altitude, is characterized by the alternation of two seasons (dry and wet). The influence of the harmattan is very pronounced during the dry season, and relative humidity can vary between 48% (March) and 80% (August). In this area, temperatures are mild and range on average between 19°C (December) and 26°C (April). Annual rainfall varies between 1,500 and 2,500 mm. Thunderstorms are frequent during the rainy season (at the beginning and end of the season).

The types of vegetation found here include gallery forests, wooded savannas, and shrubby savannas[28].

II.1.3 Upper Guinea or Guinean Savanna:

The climate of this region is influenced by continental conditions and is characterized by very low rainfall (1,500 mm per year) and wide temperature variations (31°C in April and 23°C in December). Daily temperature fluctuations can also be quite significant, especially during tornado season (at the beginning and end of the rainy season). The influence of the harmattan is very pronounced here, and atmospheric humidity ranges from 44 to 80%.

The vegetation found here consists of Sudanese savannas (wooded savannas, shrubby savannas, and savannas dotted with forest patches)[28].

II.1.4 Forest Guinea:

This region is characterized by heavy rainfall almost year-round, though rainfall levels are lower than those in Lower Guinea; nevertheless, they reach 2,000 mm to 2,700 mm and sometimes more. Relative humidity is high and nearly constant throughout the year (72% in January and 86% in August); compared to the Sudanese climate, the harmattan is weakened by the latitude and the humidity. Temperatures have a narrow range, with a high of 26°C in April and a low of 23°C in December. As for the vegetation, it is very diverse, featuring pockets of dense forest, secondary forest, clearings, and savannas in the north.The most commonly observed weather phenomena are: thunderstorms, squalls, dry mist, fog, and, in mountainous areas, hail.

Lightning strikes are frequent during the rainy season, and severe thunderstorms cause flooding. Low humidity and the harmattan wind contribute to the outbreak of bushfires, which are highly destructive to vegetation. The geographic coordinates of the study areas are presented in Table 1[28], [29].

Table 1: Geographic Coordinates of Guinea's Administrative Regions

Geographic coordinates	Conakry	Labe	Kankan	Nzérékoré
Longitude (°)	-13,71	-12,27	-9,30	-8,33
Latitude (°)	9,50	11,32	10,38	7,75
Elevation(m)	30 à 50	1067	378	467

Figure 1 shows Guinea's four natural regions.

Figure I: Study Area

II.2 Data Presentation.

The data used in this study come from the network of automatic weather stations established in 2023 by the National Meteorological Agency (ANM). About twenty stations were installed in Guinea's main regions to modernize the national climate observation system and strengthen capabilities in weather forecasting, agrometeorology, and the analysis of renewable energy potential. They are equipped with modern sensors (temperature, humidity, wind, solar radiation, precipitation, pressure) that record these parameters every 15 minutes.

The methodology is based on a rigorous approach that combines high-frequency data collection with statistical analysis. Global irradiance measurements recorded every 15 minutes were first preprocessed and converted to hourly intervals to ensure temporal consistency and facilitate energy integration. Using these hourly time series, solar energy was calculated by aggregating data across different time scales—daily and monthly—which highlights the temporal variability of solar radiation and its potential impact on photovoltaic production. MATLAB software was used to automate the calculations, manage large datasets, and generate graphical representations, thus ensuring a reproducible and scientifically reliable analysis. This methodological approach provides a solid foundation for assessing solar potential and developing energy plans tailored to Guinea's climatic conditions. The figure below shows the automatic weather station in Mamou.

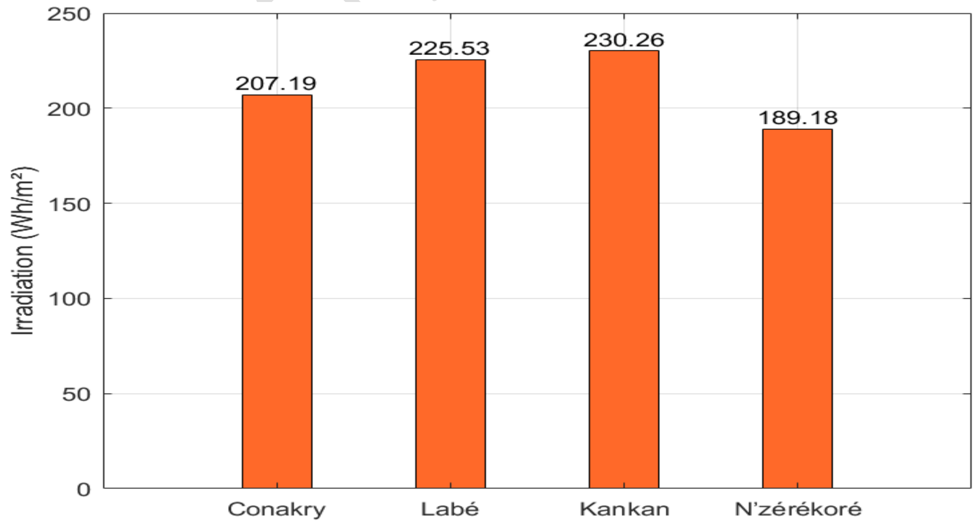
Figure 2: Mamou Automatic Station

IV. Results and Discussion

The results obtained during this study will be presented and discussed in this section.

IV.1. Total Horizontal Irradiation by Region

Figure 3 clearly illustrates the spatial variability of solar radiation in Guinea, with annual values differing by region: Kankan records the highest level at 230.26 Wh/m², followed by Labé at 225.53 Wh/m², then Conakry at 207.19 Wh/m², while N'zérékoré has the lowest value at 189.18 Wh/m². This distribution reflects the influence of local climatic conditions: the drier inland areas (Kankan, Labé) benefit from more consistent sunshine, whereas the humid forest region of N'zérékoré is hampered by heavy rainfall and dense cloud cover. Conakry, despite its humid coastal climate, maintains an intermediate potential thanks to its consistent sunshine. These



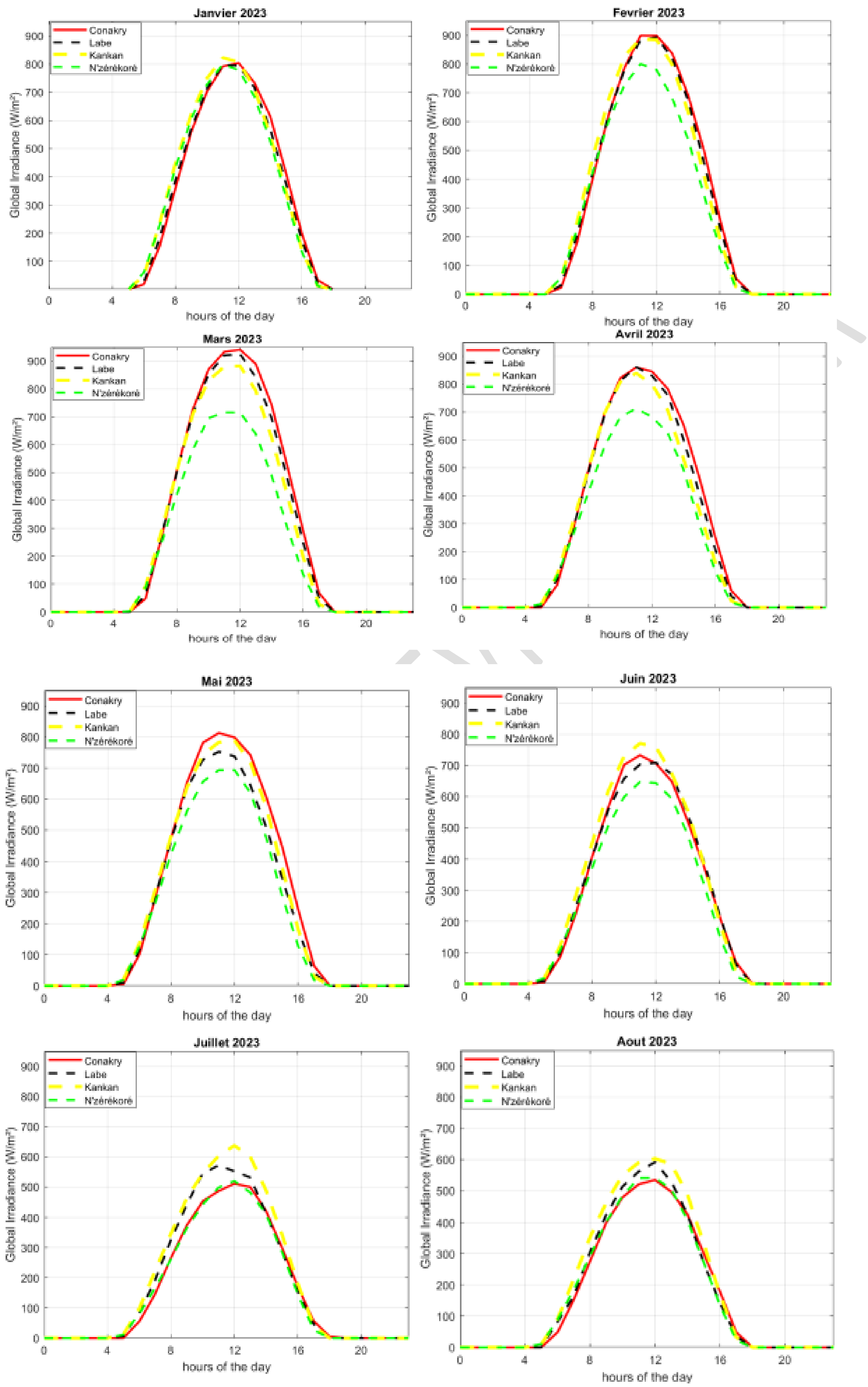
results underscore the value of prioritizing continental regions for photovoltaic development.

Figure 3: Time-series trends in solar radiation for the regions, annual average

IV.2. Trends in hourly solar radiation, daily average, available for the regions

Figure 4 shows the daily variation in global irradiance for four regions of Guinea (Conakry, Labé, Kankan, and N'zérékoré) over the 12 months of 2023. The curves follow a bell-shaped pattern typical of the solar cycle, with a gradual rise in the morning, a peak around solar noon (around 12 p.m.), and then a decline toward the end of the day. Maximum values reach approximately 800–900 W/m², reflecting intense sunshine at the zenith. The differences between regions are clear: Kankan and Labé exhibit higher and more consistent peaks, confirming their dry and sunny climate, while N'zérékoré shows lower values, a result of heavy cloud cover and abundant rainfall. Conakry, despite its humid coastal climate, maintains an intermediate profile with good stability. Seasonally, the months of February, March, April, and November appear more favorable, while July and August show a marked decline linked to the rainy season.

The figure also illustrates the spatial and seasonal variability of solar radiation. Spatially, inland regions such as Kankan and Labé have a dry climate and low cloud cover, which results in more intense and consistent sunshine. Conversely, N'zérékoré, which experiences heavy rainfall and dense cloud cover, has the lowest values, while Conakry maintains an intermediate potential thanks to its consistent sunshine despite coastal humidity. Seasonally, February, March, April, and November appear to be the most favorable months for solar production, with maximum irradiance levels near the zenith, whereas July and August—marked by the rainy season—show a significant decline. This dual variability underscores the importance of incorporating specific climatic and geographic characteristics into energy planning and climate risk management.



Janvier 2023
Fevrier 2023
Mars 2023
Avril 2023
Mai 2023
Juin 2023
Juillet 2023
Aout 2023
Conakry
Labe
Kankan
N'zérékoré
Global Irradiance (W/m²)
hours of the day

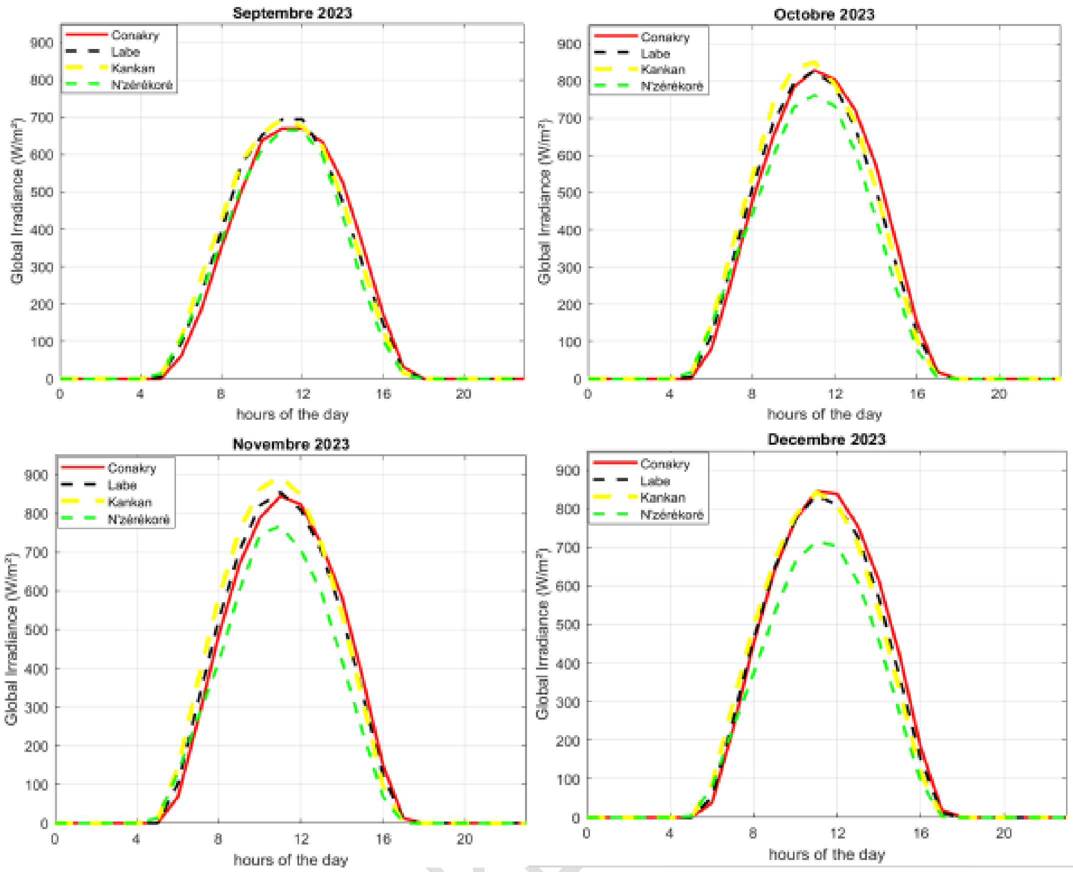


Figure 4: Trends in hourly solar radiation (daily average)

IV.3. Trends in monthly average daily solar radiation available in the regions

Figure 5 shows the monthly trends in daily solar irradiance in Guinea and highlights significant differences among the four regions studied. Kankan stands out with the highest values, reaching up to 7.74 kWh/m²/day in February and 7.45 kWh/m²/day in November, confirming its dry climate, which is favorable for solar energy. Labé follows with similarly high levels, peaking at 7.96 kWh/m²/day in February and 7.57 kWh/m²/day in March, reflecting consistent sunshine despite its elevation. Conakry, influenced by its humid coastal climate, maintains average potential with notable peaks in February (7.54 kWh/m²/day) and March (7.03 kWh/m²/day). Finally, N'zérékoré remains the least favorable, with lower values, notably 5.15 kWh/m²/day in March and 4.15 kWh/m²/day in July, a direct result of heavy rainfall and dense cloud cover. This distribution highlights the complementary nature of dry and wet areas: the former offer strategic potential for solar power, while the latter require energy planning tailored to climatic constraints.

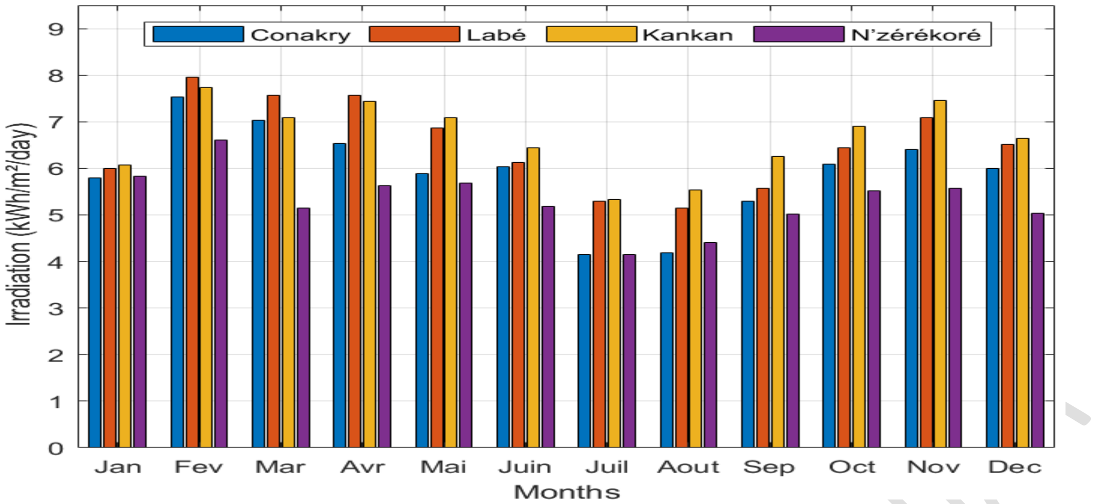


Figure 5: Trends in Monthly Average Daily Irradiation by Region

V. Conclusion

In this article, we assessed the solar potential of Guinea's natural regions using hourly total solar radiation measured every 15 minutes, covering the period from January to December 2023. The results allowed us, on the one hand, to identify the solar potential of each natural region in Guinea and, on the other hand, to show that the regions of Kankan, Labe, and Conakry are the sunniest, with solar radiation levels of 230.26 Wh/m², 225.53 Wh/m², and 207.19 Wh/m², respectively, which correspond to average monthly daily irradiation of 6.67 kWh/m², 6.51 kWh/m², and 5.91 kWh/m². The N'zérékoré region is the least favorable, with total solar radiation of 189.18 Wh/m² and a monthly average irradiance of 5.32 kWh/m².

The trend in monthly total available solar radiation at the sites shows that February, March, April, and November are the sunniest months in all regions of the country. By analyzing hourly variations, we observed that peak solar radiation is generally recorded between 11:00 a.m. and 12:00 p.m. across the regions.

A comparison of the daily solar radiation trends across regions also shows a good correlation in solar radiation levels.

Due to a lack of data, the study was conducted over a period of only one year for all four sites. To better validate the methodology used, it will be important to conduct the study over a significantly longer period (20 to 30 years) and during the same time frame.

Looking ahead, we plan to use this method to assess the solar potential of all prefectures in Guinea and throughout the subregion in order to create a map of solar potential for the entire country and the West African subregion.

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