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Analytical study of global solar radiation and climate data for solar energy system applied at south of Libya

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ABSTRACT

Increasing of the energy demand and the global concern about preserving the environment using fossil fuels has led to the use of environmentally friendly renewable energies. The most reliable renewable energy is solar energy. It is an abundant and practically limitless source of energy. This paper conducts a statistical analysis of solar radiation and the impact of other weather factors on it. The solar radiation is an important factor in determining or designing solar energy systems. We analyzed a data of four cities located in western, eastern, northern and southern Libya. Microsoft Excel used to conduct this analysis and simulated 1 kWp of PV modules by SAM software for the four cities to know the amount of its annual productivity. Comparison and statistically analysis between them are in terms of global solar radiation, relative humidity and temperatures. The results showed that the city of Sebha has the highest average daily solar radiation compared to other cities with the strongest annual productivity reaching 1833 kWh/kWp year. Which makes it more amenable to a solar energy system.

دراسة تحليلية للإشعاع الشمسي العالمي والبيانات المناخية لنظام الطاقة الشمسية المطبق في جنوب ليبيا

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الكلمات المفتاحية:
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الملخص

أدى تزايد الطلب على الطاقة والقلق العالمي بشأن الحفاظ على البيئة باستخدام الوقود الأحفوري إلى استخدام الطاقات المتجددة الصديقة للبيئة. والطاقة المتجددة الأكثر موثوقية هي الطاقة الشمسية. وإنها مصدر وفير وغير محدود عملياً للطاقة. تجري هذه الورقة تحليلًا إحصائيًا للإشعاع الشمسي وتأثير عوامل الطقس الأخرى عليه. يعتبر الإشعاع الشمسي عاملاً مهماً في تحديد أو تصميم أنظمة الطاقة الشمسية. قمنا بتحليل بيانات أربع مدن تقع في غرب وشرق وشمال وجنوب ليبيا. تم استخدام برنامج مايكروسوفت اكسيل لأجراء هذا التحليل ومحاكاة 1 كيلوواط من الوحدات الكهروضوئية بواسطة برنامج سام للمدن الأربعة لمعرفة مقدار انتاجيتها السنوية. المقارنة والتحليل الاحصائي بينهما من حيث الاشعاع الشمسي العالمي والرطوبة النسبية ودرجات الحرارة. وأظهرت النتائج أن مدينة سبها تتمتع بأعلى متوسط إشعاع شمسي يومي مقارنة بالمدن الأخرى مع أقوى إنتاجية سنوية تصل إلى 1833 كيلوواط/كيلوواط ساعة/كيلوواط في السنة. وهو ما يجعلها أكثر قابلية لنظام الطاقة الشمسية.

1.Introduction

A countries prosper economically and sustainably depends on its ability to generate and deliver energy. The majority of the world's countries have increased their use of traditional energy sources to generate electricity, which has led to major environmental challenges such air pollution, global warming, and health-related difficulties. This calls for a shift in the sorts of energy sources that are used to rescue the globe, and this have become necessary since there is a need for safe, plentiful, and environmentally friendly energy sources[1]. Globally, scientists and engineers are actively working to find alternative energy sources. The most prevalent ones are transformed into electrical power[2], including solar electromagnetic radiation[3]. One of the most significant categories of renewable energy sources is solar energy, and the forecast, analysis, and design of systems that use it all depend on knowledge of the solar radiation levels

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worldwide.

Libya is among the nations that benefit most from solar energy. On a level coastal plain, it is possessing an extremely high daily solar radiation rate of almost 7.1 kw/m²/day, while in the southern parts, it is approximately 8.1 kwh/m²/day[4]. Analysis of solar radiation data is an important tool in the accurate designing/sizing of solar Photovoltaic (PV) systems and conducting performance analysis of the system[5].

In this paper, we will conduct an analytical study of four cities from different regions of Libya, including a statistical analysis of solar radiation and other climatic data on the one hand and the production of 1 kWp per year for all cities on the other hand.

2.Data and methodology

2.1.Study zones

In general, Libya is characterized by solar radiation, but its amount varies from region to region. Each region in Libya has certain climatic conditions such as temperatures, sunshine hours and relative humidity. Solar radiation in the southern region is different from the areas located on the coast. Therefore, the southern region is considered more fortunate to invest in solar energy. We selected four cities located in west, south and east-central of Libya, as shown in figure 1 and geographical details in table 1. Comparison and statistically analysis between them are in terms of global solar radiation, relative humidity and temperatures.

Fig 1 A map showing some of the cities selected for the study.

Table1.Geographical details of some cities in Libya.

Location	Latitude [deg]	Longitude [deg]	Altitude [m]
Tripoli	32.8˚N	13.2˚E	81
Sebha	27.0˚N	14.4˚E	420
Sirte	31.2˚N	16.5˚E	28
Benghazi	32.1˚N	20.1˚E	2

- **Data**

The data used in this study are daily average monthly solar radiation, ambient temperature and relative humidity for 12 years (2011–2022) and were collected from the NASA[6] as shown in following figures 2,3&4.

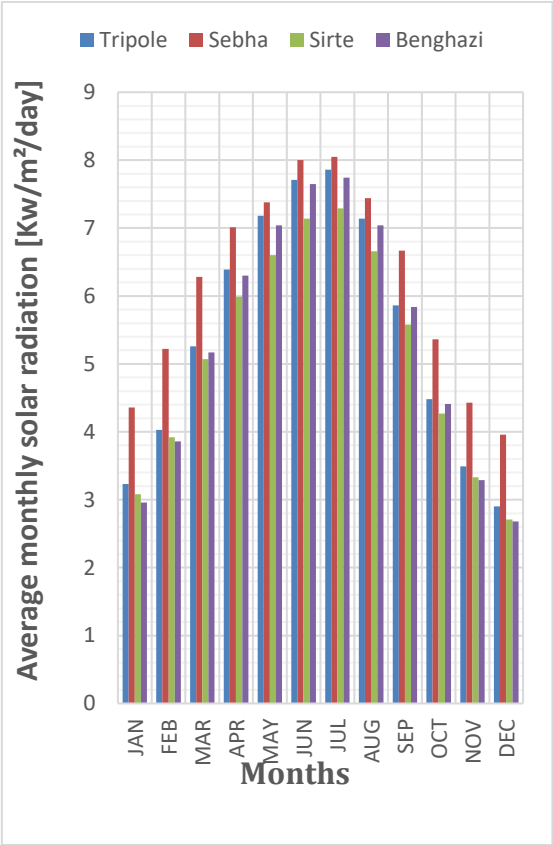

Fig 2 Data comparison of solar radiation between some Libyan cities.

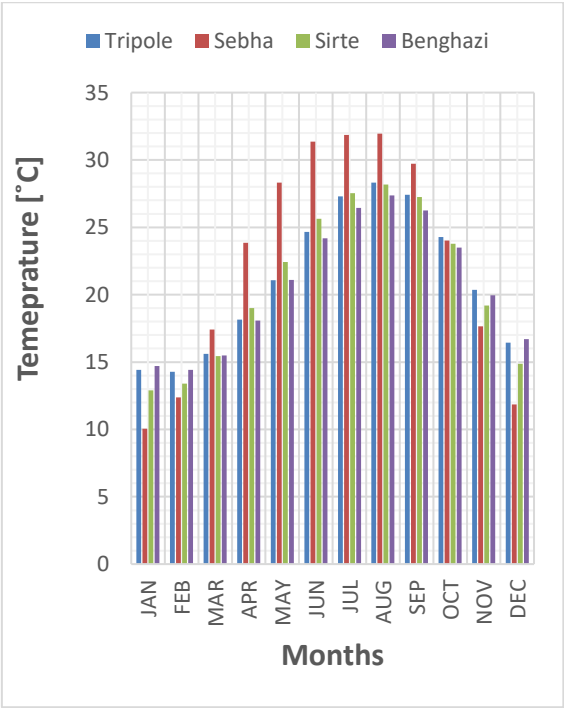

Fig 3 Data comparison of temperature between some Libyan cities

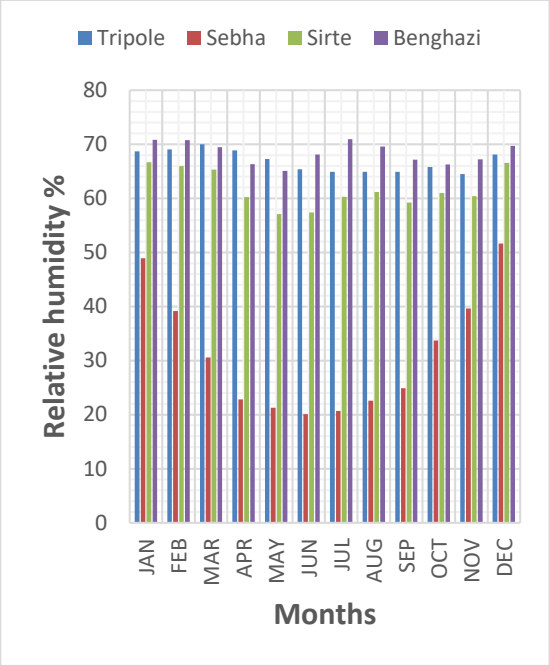

Fig 4 Data comparison of relative humidity between some Libyan cities.

2.2.Methodology

The methodology used in this study was in two stages, the first stage was statistical analysis. We used statistical measures to find out the correlation and regression to analyze the data for each city.

The Coefficient of Correlation (R) was used if there is a relationship between two variables, and then we can make predictions about one from another. The relationship between solar radiation and temperature is on the one hand, and the relationship between solar radiation and relative humidity on the other. To study and analyze the impact of a quantitative variable on another quantitative variable, we conducted these statistical analyzes using the Microsoft Excel 2016 program.

The second stage made a comparison in terms of energy production by simulating **1 kWp** of PV modules using **SAM** software based on the data of each city. We considered that all PV modules are oriented in the south direction and the tilt angle is equal to the latitude of each city where (**β=φ**).

β : Tilt angle of the solar panel.

φ : Latitude of the site.

3.RESULT AND DISCUSIONS

The results of the correlation coefficient (R) between solar radiation and temperature in all cities were directly correlated with varying percentages. The strongest correlation was in Sebha (R=0.89), followed by Sirte (R=0.75), Benghazi (R=0.69), and Tripoli (R=0.67), respectively.

The correlation between solar radiation and relative humidity in all cities was inversely correlated. The correlation between solar radiation and relative humidity varied. It was highest in Sebha (R=-0.96), followed by Sirte (R=-0.74), Tripoli (R=-0.37), and Benghazi (R=-0.23).

Figures 6 and 7 for all cities show the relationship between individual temperature versus solar radiation and relative humidity versus solar radiation.

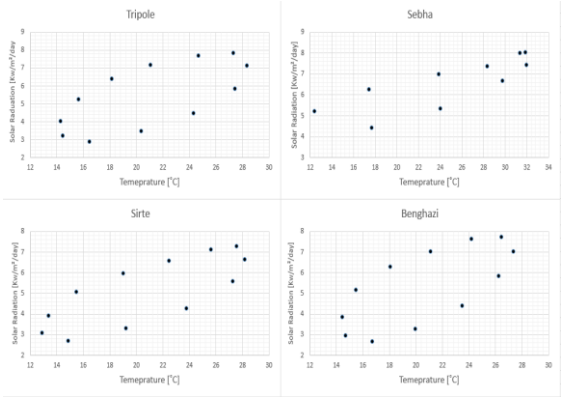

Fig 5 Relationship between temperature and solar radiation for all cities.

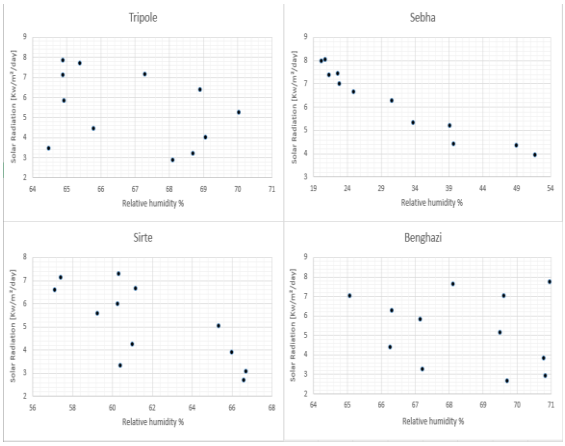

Fig 6 Relationship between relative humidity and solar radiation for all cities.

To study the energy output implications for different average solar radiations of the cities, an installation of 1kWp was assumed. We simulated with SAM software the highest energy productivity in the city of Sebha was 1833 kWh/kWp throughout the year, and the outcome from three other cities were close in productivity. In Tripoli had 1596 kWh / kWp. Benghazi and Sirte were 1587 kWh / kWp and 1579 kWh/ kWp respectively. The figure 7 shows the monthly energy productivity for all cities.

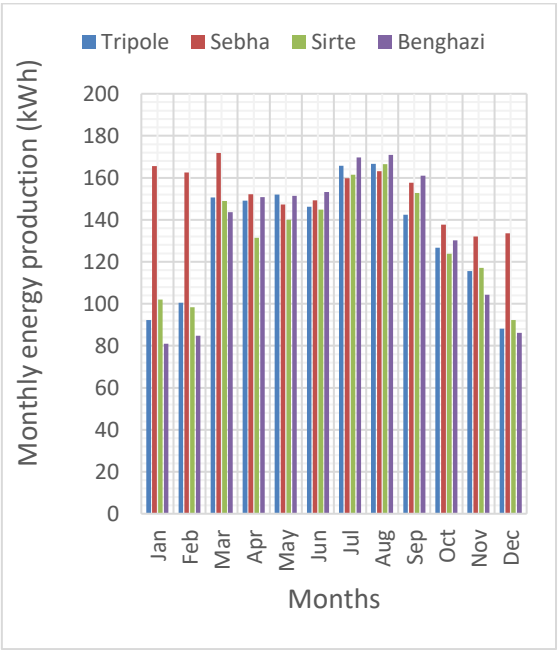

Fig 7 Monthly energy production per kWp from pv modules for all the cities.

4.Conclusion

The city of Sebha has the highest average monthly solar radiation compared to other cities, which making it more amenable to a solar

energy system. In terms of statistical analysis, the correlation coefficient, which describes the relationship between solar radiation as a dependent variable and temperature and relative humidity as independent variables, showed us that the strongest correlation between solar radiation and temperature in Sebha city compared to the other cities, where the correlation between solar radiation and temperature (R=89) was positive and between solar radiation and relative humidity (R=-96) was negative. It is considered that the higher the average solar irradiance, the lower the project cost of a solar PV system. Simulating the productivity of 1 kWp of PV modules showed that the strongest productivity is in the city of Sebha, with 1833 kWh/kWp year.

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