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Review Paper

Study of solar irradiance at low land Simara Nepal, using Angstrom's empirical model

Gaurav Kunwar[1*] and Khem Naryan Poudyal[2]
[1]Department of Physics, Patan Multiple Campus, T.U. Nepal
[2]Institute of Engineering, Tribhuvan University, Nepal
kgaurav6650@gmail.com

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Abstract

The daily solar irradiance was measured using CMP6 first class Pyranometer of the low land region Simara (27.16^0 N, 84.98^0 E) Nepal. The solar radiation coming to earth surface primarily depends on the climate conditions. In developing countries like Nepal, there is no sufficient reliable data of solar irradiance and measuring instruments. In the absence of sufficient data there is a need of an empirical model to estimate the solar irradiance which seems very important in every region of Nepal. This empirical model use several meteorological parameters among them sunshine hour are mostly and commonly used parameters. The least square regression is performed to derive these constants. The measured and predicted solar irradiance were tested using mean percentage error (MPE), mean bias error (MBE) and root mean square (RMSE) Further, we calculated corresponding value of coefficient of determination (R^2). The predicted and measured values get close to each other and hence they are remarkable. Finding regression constants are used to predict the GSR at that location for further utilization. This Solar energy can be utilized to mitigate energy crisis at that location. In addition, this finding also helps to grow more crops or foods on the basis of rainfall, sun shine hour, humidity, temperature.

Keywords: Solar irradiance, Affecting factor, Empirical model, Sunshine hour.

Introduction

The sun is the source of all kinds of energy which remains vital from the human civilization began. In Greek mythology, the sun is the god. So it remains main principle from the beginning and till now[1]. Any activity depends on the energy and capability to do work relatively depends on the amount of energy. The human beings use the energy from food which may be the plant, meat, and many more. On other hands, people also discovered the energy which can be gained through the cooking food. When the time passes, Human developed the new technique to use energy by training animals to work them. After the Second World War, several energy sources were introduced like nuclear energy in which large amount of energy were produced. There were impulsive and unpredicted barrier in supplying petroleum to the world in 1973.

The people were really frustrating and no longer to ride their vehicles because of this barrier. This made people to vex deeply about how deficient they were with the energy. Since 1980s the harmful effect of global warming caused by fossil fuels were becoming widespread which lead global society to communicate to consider some fruitful steps as to rid. In one hand the cost of fossil fuels were augmented and on other hand cheap and secure petroleum were extinguished. Under this case, economic growth looked impossible to gear up unless the reliable energy is made accessible which further focused the attention on alternative energy resources[2].

In today's growing energy needs and increasing some environmental concerns, alternatives non-renewable and non-polluting fuels have to be investigated. Such alternative is simply called solar energy[3]. The solar irradiance coming to the earth surface plays vital role to change physical, chemical and biological phenomena[4]. Despite of these crucial important, for developing country like Nepal it is more difficult to measure solar irradiance due to economic and technical constraint. Hence it is essential mathematical model which help to estimate the average total solar irradiance[5].

As we know solar radiation which is renewable energy source in the nature which holds vital role in designing energy conversion devices[6]. The study of global solar radiation includes several parameters like rainfall, sunshine hour, relative humidity, maximum temperature, minimum temperature, wind direction[4]. During the study of solar radiation it's component at given place are the main input source for some phenomena like photovoltaic.

It is better to install measuring instrument Pyranometer at these measuring locations[7]. This is because the accurate data obtained from the device is indispensible for several research sites[8].

An accurate knowledge of solar irradiance is required by solar engineers, hydrologists in many applications of solar energy[9]. Lack solar irradiance is important factor for the study of most crop climate change[10]. The correlation technique is used to calculate monthly average global solar irradiance which was purposed by modified Angstrom empirical model. He used sunshine hour as main parameter. These correlation is used to predict the values of the monthly average daily global solar irradiance for the locations having similarities[6,11].

In Nepal 83 percentage of total population live in rural areas. Many peoples are still deprived of getting hydroelectricity, petroleum and so on. So peoples are forced to use kerosene lamps as an alternative electric light. In Nepal nearly 84 percent of total energy consumption comes from woods, agricultural residue, and cattle dung which are the main source of heating and lightening. In 2010 the energy consumption pattern has changed drastically then previous years which clearly showed that residential areas consuming energy (87 percent), transport (6 percent), industry (5 percent) and (25 percent) of the earned foreign currency is used to import petroleum which was the 10.8 percent greater than previous years[12].

Today, nearly about 68 percent of total populations are using light through hydropower. Nepal has giant potential to produce hydropower (4200 MW) but only 2 percent has been used due to various obstacles. Solar energy is the main energy source in such case. The government of Nepal has given financial aids to promote renewable energies sources like solar energy.

Because of obstructing facture like greenhouse gases and atmospheric pollution, there is no more solar irradiance. The less solar irradiance is found in eastern highland than central, mid hill region and western hill of Nepal because of higher range of humidity, precipitation and wind[12].

There are several empirical formulae to estimate the monthly mean daily global solar radiation which is the function of climate data[6,13,14].

Methods and Instrumentation

The primary data of daily solar radiation on horizontal surface for Simara were collected from archives of the Department of Hydrology and Meteorology, Government of Nepal (DHM/G0N). Data were measured using first class CMP6 Pyranometer. Daily Sunshine hour, maximum temperature and average temperature data for the site low land Simara (latitude 27.16^0, longitude 84.98^0 and altitude 137m) were obtained from Department of Hydrology and Meteorology (DHM/GoN).

Theory: The correlation relation to estimate the monthly daily solar radiation on horizontal surfaces using sunshine hour as a meteorological parameter given by Angstrom[15] and prescott[16] is in the form

$$\frac{H_g}{H_0} = a + b\left(\frac{n}{N}\right) \quad (1)$$

Where: a and b are empirical constant obtained from regression analysis. n is the sunshine hour, N is the day number of the year (DoY), H_g is the measured global solar radiation and H_0 is extraterrestrial GSR which both are measured in MJ/m^2/day. Mathematically,

$$H_0 = \frac{24}{\pi} I_{sc}\left(1 + 0.033\cos\frac{360n}{365}\right)\left[\frac{\pi}{180}\omega\sin\emptyset\sin\delta + \cos\emptyset\cos\delta\sin\omega\right] \quad (2)$$

Where: I_{sc} is the solar constant which is given as

$$I_{sc} = \frac{1367\times3600}{1000000}\ \text{MJ/m}^2\text{/day} \quad (3)$$

Where: n is the day of the year from n=1 to n=365. ω is hour angle, ∅ being latitude and δ is the declination angle. Whose expressions are given as,

$$\text{Day length } (N_d) = \frac{2}{15}\cos^{-1}(-\tan\emptyset\tan\delta) \quad (4)$$

$$\delta = 23.45\left[\frac{360(N+284)}{365}\right] \quad (5)$$

$$\omega = \cos^{-1}(-\tan\emptyset\tan\delta) \quad (6)$$

Results and discussion

Table-1: Meteorological Data and GSR at low land, Simara in 2013.

Months	n	N	n/N	H_g (MJ/m^2/ day)	H_0 (MJ/m^2/ day)	$\frac{H_g}{H_0} = K_T$
Jan	5.4	10.4	0.51	8.2	20.1	0.40
Feb	7.3	11.0	0.66	11.3	27.1	0.41
Mar	8.5	11.8	0.72	13.9	32.6	0.42
Apr	8.8	12.6	0.69	16.3	37.3	0.43
May	8.0	13.3	0.60	18.4	39.9	0.46
Jun	6.1	13.6	0.44	13.9	40.7	0.34
Jul	6.3	13.5	0.46	12.4	40.0	0.31
Aug	6.8	12.9	0.52	12.7	37.7	0.33
Sep	8.1	12.1	0.66	13.4	33.5	0.40
Oct	7.3	11.3	0.64	11.6	28.0	0.41
Nov	9.0	10.6	0.84	11.9	22.4	0.53
Dec	6.6	10.3	0.64	9.2	21.2	0.43

The Figure-1 shows that value of clearness index and relative sunshine hours are higher in November. While lower at January due to rainfall and local weather conditions. It further shows that there exist almost same trend in between sunshine hour and measured GSR. The sunshine hour is directly proportional to the GSR. Further it indicates that sunshine hour increases initially up to April thereafter, it decreases as more rainfall and cloudy days noted. After being lowest at July, it raised significantly due to clear sky conditions.

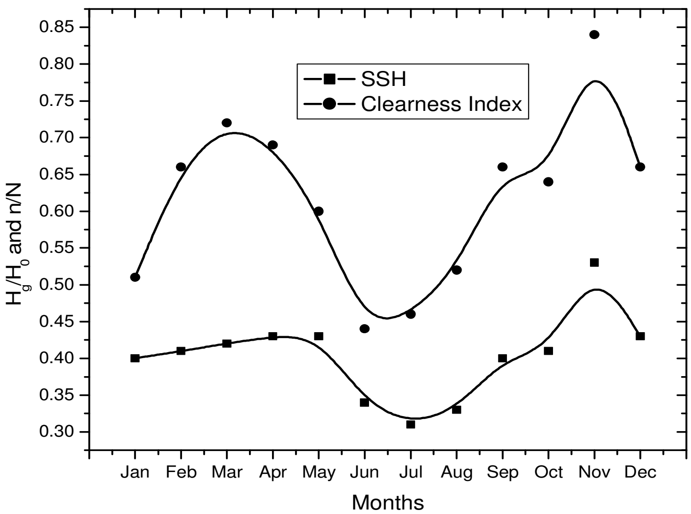

Figure-1: Monthly Average Clearness Index and Relative Sunshine hour in Simara, 2013.

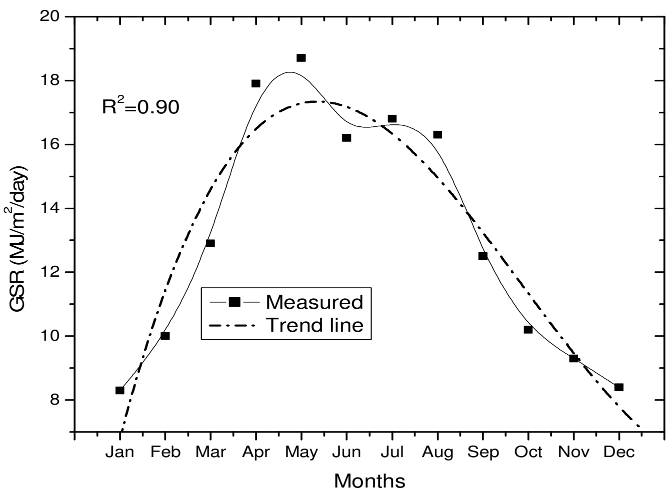

Figure-2: Monthly mean variation of GSR of Simara for 2013.

The annual average measured value of GSR is 12.7 ± 1.40 MJ/m^2/ day. The coefficient of determination and p values are 0.90 and <0.016. The coefficient of determination signifies that 90 percent of the data are closer to best fit.

Estimation of global solar radiation using different parameters: The measurement of global solar radiation is very expensive, time consuming, risk of maintenance.

Hence it is essential to propose a convenient alternative to be used as a solar estimator based on various meteorological parameters. Among many empirical equations, the most widely used equation is modified Angstrom empirical equations. The modified form of Angstrom equation for Simara in 2013 is obtained as.

$$\frac{H_g}{H_0} = 0.43 + 0.06\left(\frac{n}{N}\right) \tag{7}$$

$$\frac{H_g}{H_0} = 0.20 + 0.004T_{Max} \tag{8}$$

The monthly mean variation of GSR with Estimated GSR given by equation 7 is given below in Figure-3.

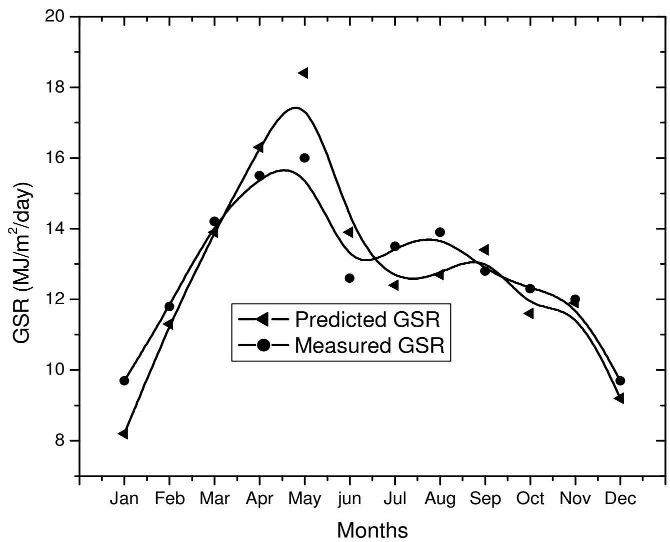

Figure-3: Monthly mean variation of GSR with estimated GSR of Simara, 2013.

The monthly mean variation of GSR with Predicted GSR given by equation 7 is shown below in Figure-4.

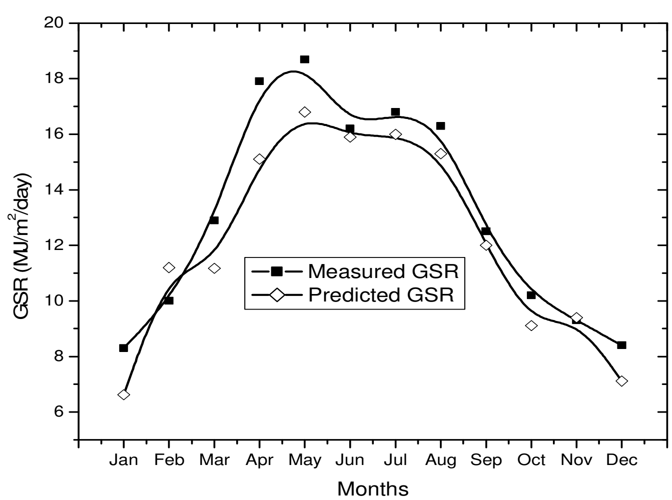

Figure-4: Comparison between the measured and predicted GSR of Simara for 2013.

Estimation of GSR using regression coefficients: The modified Angstrom relation is used to estimate the GSR and regression technique. The obtained empirical constant from the year 2013 are used to estimate the GSR for years to come and also found RMSE, MBE, MPE, R^2 we concluded that adopted model gives the best values of GSR. The linear form of measured value of GSR versus estimated value of Simara for year 2013 as given by the empirical equations 7 and 8 are shown below.

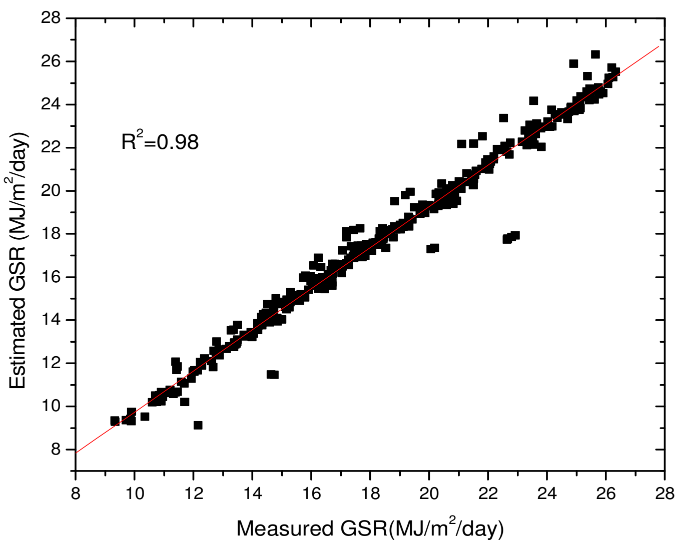

Figure-5: measured vs estimated GSR in samara in year 2013.

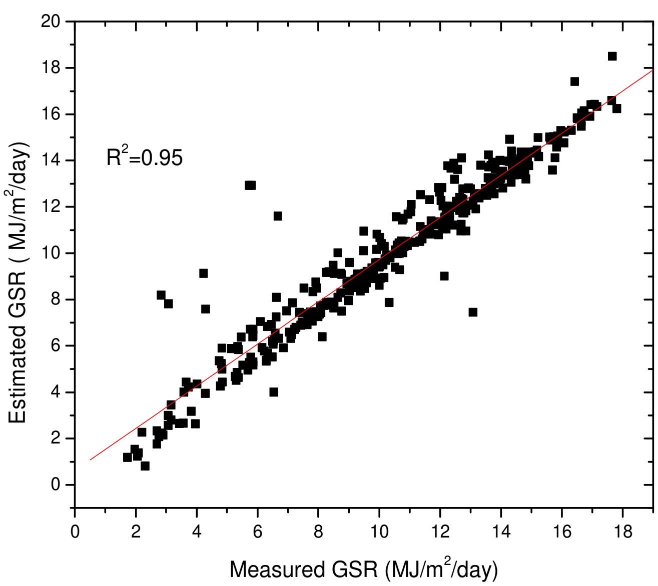

Figure-6: Measured vs estimated GSR in samara for 2013.

Figure-5 and 6 signify that the linear relation between global solar radiation with various meteorological parameters showed best fit to the observed data which aims to derive a good relationship that may be used to predict the values of GSR.

Conclusion

The empirical constants 0.43 and 0.06 are found at Simara for the year 2013. The modified Angstrom's equation with the values of coefficient of determination can be used to design and predict in the localities that do not have same solar radiation but have similar geographical regions. The value of GSR calculated by modified Angstrom results are validated by various statistical tools like MBE, RMSE and MPE.

The annual average measured GSR of Simara for years 2013 12.7± 1.40 MJ/m^2/day. The predicted GSR at low land Simara is in satisfactory with measured GSR given by linear regression model. Finally, it is concluded that the finding empirical constants and meteorological parameter are utilize to find the GSR for the year to come at similar geographical sites.

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