BIBECHANA

ISSN 2091-0762 (Print), 2382-5340 (Online)

Journal homepage: http://nepjol.info/index.php/BIBECHANA

Publisher: **Department of Physics, Mahendra Morang A.M. Campus, TU, Biratnagar, Nepal**

Estimation of Global Solar Radiation (GSR) From the Sunshine Hour of Guranshe, Surkhet, Nepal

Homchandra Adhikari and Nurapati Pantha*

Central Department of Physics, Tribhuvan University, Kirtipur,Kathmandu, Nepal
*Email: mrnurapati@gmail.com

Article Information:
Received: April 17, 2021
Accepted: October 30, 2021

Keywords:
Solar Energy
Meteorological Parameter
Global-Solar Radiation
Sunshine hour

ABSTRACT

The variation in Global Solar Radiation (GSR) was studied by using experimental data via an automatic weather station (CMP3 pyranometer) located at Guranshe (Surkhet), a hilly area with elevation 2194m from the sea level. Also, the estimated sunshine hour data of the area were used to calculate the GSR for the purpose of comparison with the measurements. Our study finds a good agreement between the measured (15.65 $MJ/m^2/day$) and estimated/calculated (19.18 $MJ/m^2/day$) values of annual average GSR. The estimated GSR uses Angstrom-Prescott type model for calculating sunshine hours, and the coefficients ($a=0.28$) and ($b=0.57$) were obtained using the Sangeetas and Tiwari model. The annual average estimated sunshine hours was found to be 6.86hr which is suitable for GSR based applications. The measured data were used to study the seasonal, monthly and diurnal variations of GSR. The maximum and minimum values of GSR were found during the spring and summer seasons respectively. The minimum GSR in summer is because of heavy rainfall, high relative humidity, and cloud formation in the sky during the time. The coefficient of regression(R) and the coefficient of determination (R^2) were obtained as R=0.881 and R^2=0.776 respectively. Here the high value of R (88.1%) indicates that of dependent variable (GSR) is nicely predicted by the independent variables. Also the coefficient of determination (R^2) tells us the strength of the relationship between two variables.

DOI: https://doi.org/10.3126/bibechana.v19i1-2.46408

1. Introduction

Energy is one of the basic needs for all living creatures on earth surfaces without which our universe would be no more than a frozen rock. The radiation received by the earth from the sun in the form of electromagnetic radiation, that is radiant energy, is the main source of energy on the earth's surface. Renewable, non-renewable, and ultimate sources of energy obtained on the earth's surface, among with all the energy sources, are directly or indirectly controlled by the solar energy [1]. Photovoltaic and solar thermal capture is the main techniques to exploit the solar energy which are among the cheapest and fastest-growing sources of power in worldwide.

According to the Nepal Electricity Authority (NEA) report of the fiscal year 2019/2020, the total population accessing electricity reached to 86% of the total households. The power stations generated a total of 3021 GWh of electricity which is 18.57% higher than the fiscal year (FY) 2018/2019 [2]. Biomass, hydroelectricity, petroleum products, natural gas, and coal are the major energy resources in Nepal, where 78% of people have access to grid-connected energy, 82% use solid fuels such as dung, coal, and wood as cooking energy. Ninety five percent (95%) of biomass, which is casing harmful impact in environment, is predominantly used for household purposes. Petroleum, an imported and non-renewable type of energy, is the second largest energy fuel in Nepal [3]. Hence the solar energy can be considered as one of the best, easily accessible, and renewable type of energy sources for Nepal.

Fossil fuels directly affect the environment and human health. Also they are expensive. Large hydropower projects have several problems such as landslides, sedimentation, and damage to aquatic life, ecosystem, and vegetation. There are some social challenges such as rehabilitation and cultural issues. Hence the solar power which is environmentally friendly, readily available, and cheap, and can be installed at any location can be a good alternative source of energy [4]. However, an accurate knowledge of the meteorological parameters and location of the site should be well known before installing solar devices. Atmospheric energy balance studies, photovoltaic and agricultural studies, thermal load analysis on buildings, and meteorological forecasting should be reliable and readily available for the optimization design and performance evaluation of solar technologies [5].

Energy transfer from the sun to the earth's surface in the form of electromagnetic waves is called solar radiation. Different atmospheric particles like air molecules, ozone, clouds, and water vapor deplete the incoming radiation through reflection, scattering, and absorption [1]. There are other metrological/geological factors that affect the energy density of the incoming solar radiation (extraterrestrial solar radiation). They include rainfall, relative humidity, air pressure, air temperature, solar zenith angle, precipitation, latitude, sunshine duration, solar declination, and earth atmosphere [6]. Here the GSR is defined as the sum of the direct, diffused, and reflected radiation.

Different models can be used to calculate GSR, however, the availability and the relevancy of meteorological parameters determine the model to use in particular territory. In the context of Nepal, limited number of studies have been carried out on the estimation of GSR due to rare meteorological stations and lack of complete data of climatic factors. Adhikari et al. (2013) estimated the GSR for Biratnagar, Kathmandu, Pokhara, and Jumla which are at

72m, 1350m, 800m, and 2850m above the sea level using the Angstrom-Prescott model. They observed excellent agreement between the measured and estimated values of GSR where the maximum and the minimum solar radiation (SR) were found in Jumla and Biratnagar respectively [3]. Temperature and Relative Humidity (RH) based models have been used by Adhikari et al. (2014) to estimate the GSR. They observed that temperature and GSR have a direct relationship whereas RH and GSR have an inverse relationship. They also observed a strong correlation between the observed and estimated values [7]. The GSR was estimated and studied on a horizontal surface of Nepalgunj (low altitude) by using RadEst 3.00 software with four models [8]. The CMP6 pyranometer was used to measure GSR at Simara airport, Bara Nepal for the years 2009 and 2010. Two models, Angstrom-Prescott[9], and Sangeetas and Tiwari models [10], were used to estimate the GSR and observed that GSR were maximum in March, April and May due to the sunny and clear weather and the minimum was found in summer. Elom and Nnamdi (2012) used a regression model and estimated the GSR and average temperature during the period of 11 years (1996-2006) at Onitsha, Nigeria, and found that model equations give excellent results and show a strong correlation between solar radiation (SR) and air temperature. They also observed 87.1% of the variation in the monthly mean daily SR on a horizontal surface [6]. Kumar et al. (2013) developed a new model based on the Angstrom-Prescott model in North India, Himanchal Pradesh, and observed that by using a new model they determine the regression constant with only latitude and longitude. Previous model used to use other parameters, in addition to latitude and longitude, as well and found that the new model is far better [5]. Elekalachi et al. (2016) used an Angstrom-type regression equation to estimate GSR on horizontal surfaces for Awaka, Enugu, and Owerri with the data from archives of the National Aeronautics and Space Administration (NASA) for a period of 11 years (2000-2010) [10].

Here we use the empirical model to estimate the global solar radiation by estimating the sunshine hour data. In addition to the GSR and the sunshine hour, we study the impact of meteorological parameters on global solar radiation in Guranshe, Surkhet Nepal. Finally, we analyze the month and season wise GSR values and suggest the possibility of harvesting solar energy in near future.

2. THEORY AND METHOD

Description of the site

The automatic weather station is located at Guanshe which lies in the Surkhet district and border between Surkhet and Dailakh. It is about 600 km west of the national capital Kathmandu and is situated at latitude 28^{o}39'22"N and longitude 81^{o}37'45"E in the inner terai valley of Nepal. It elevates 2194 m above from the sea level. It has a moderate climate, which contains the mountainous region and outer terai region. Average temperature range from 37.1^{o}C maximum to 4.5^{o}C minimum [11]. The location of the weather station is shown in Figure 1.

Fig.1: Automatic weather station at Guranshe, Surkhet (Provided by the Department of Hydrology and Meteorology, Government of Nepal) [12].

The daily solar radiation on a horizontal surface for Guranshe, Surkhet was collected from archives of the Department of Hydrology and Meteorology, Government of Nepal (DHM/GoN) for the year of 2018. Daily data of average air temperature, air pressure, relative humidity, rainfall for the site were obtained from DHM/GoN. CMP3 pyranometer **(**Figure 2**)** was used to measure global solar radiation on a horizontal surface.

2.2 Collection of plant materials

The plant materials (plant & rhizomes) (Figure 1) were collected in August 2018 from the Salyan district (Tharkot hill, altitude: 2,400 m above sea level), Karnali province, Nepal. The herbarium of the plant was identified and authenticated as *Bergenia pacumbis* (Buch.-Ham. Ex D. Don) C. Y. Wu & J. T. Pan by Taxonomists in National Herbarium and Plant Laboratories, Lalitpur, Nepal. The rhizomes were washed with tap water followed by sterilized distilled water to remove the adhered dust, dirt, and other foreign materials and dried in shade at room temperature. The dried rhizomes were powdered and then stored in an airtight polyethylene bag in a cool,
dry location for ongoing studies.

Fig.2: CMP3 Pyranometer [13].

Theoretical detail

The Angstrom-Prescott, and Tiwari and Sangeeta model [7] are used to calculate the GSR theoretically on a horizontal surface with the help of estimated sunshine hour of the year 2018 for Guranshe, Surkhet. The model is given by:

$$\frac{H}{Ho} = a + b\left(\frac{n}{N}\right) \ldots (1)$$

Where H is the Monthly average daily GSR on the horizontal surface, Ho is the Monthly average daily extraterrestrial radiation, n is the monthly average daily number of hours of bright sunshine, N is the average daily number of possible sunshine, a and b are the regression constant.

M. Adb. Elwashed and R.L Syder [14] in their paper have presented a regression equation which is based on the monthly daily temperature. We use equation (2) to estimate the sunshine hour data of Guranshe, Surkhet.

$$n = 4.352 + 0.232T \ldots (2)$$

Where n is the sunshine hour and T is the average daily mean temperature.

The extraterrestrial solar radiation (Ho) on a horizontal surface is given by, Iqbal [5] as follows:

$$Ho = \frac{24}{\pi} * IscEo[(\frac{\pi}{180})\omega s(Sin\delta Sin\emptyset) + (Cos\emptyset Cos\delta Sin\omega s)] \ldots (3)$$

Where Isc and Eo are the solar constant and eccentricity correction factor which is given as,

$$Isc = \frac{1367*3600}{10^6} \text{MJ/m}^2\text{/day}$$

$$Eo = 1 + 0.33Cos\frac{360Nd}{365}$$

Where, Nd is the day of the year, Julian days (1^{st} January, Nd=1 and 31^{th} December, Nd=365). ωs is hour angle, ∅ being latitude of site and δ is the solar declination which can be calculated as,

$$\omega s = arcCos(-tan\emptyset tan\delta)$$

And

$$\delta = 23.45[\frac{360(Nd + 284)}{365}]$$

The maximum possible sunshine hours or day length can be calculated as,

$$N = \frac{2}{15} arcCos(-tan\emptyset tan\delta) \ldots (4)$$
$$= \frac{2}{15}\omega s$$

The regression coefficients a and b are calculated by using Sangeeta and Tiwari model [10, 15] by,

$$a = -0.110 + 0.235cos\emptyset + 0.323\frac{n}{N} \ldots (5)$$
$$b = 1.449 - 0.553cos\emptyset - 0.694\frac{n}{N} \ldots (6)$$

Where, $\emptyset$ is the latitude of the particular location.

To predict the accuracy of the model and also to know how the calculated GSR (Hc) varies with measured GSR (Hm) following statistical test is done

$$RMSE = \left[\sum_{i=1}^{n} \frac{(Hic-Him)^2}{N}\right]^{\frac{1}{2}} \ldots (7)$$

Where, n is the number of data i.e. several months, Him is the i^{th} measured value, Hic is the i^{th} calculated value and N is the number of observations. Root Mean Square Error (RMSE) measures how much error is obtained between the calculated and the measured data set. Also tells us that how the calculated GSR deviates from the measured GSR.

$$MBE = \frac{\sum_{i=1}^{n}(Hic-Him)}{N} \ldots (8)$$

Mean Bias Error (MBE) is an indication of the average deviation of calculated values from the measured values.

$$MPE = \frac{\sum_{i=1}^{n}\frac{(Him-Hic)}{Him} * 100}{N} \ldots (9)$$

Mean Percentage Error (MPE) is the computed average of the percentage of errors by which the calculated value of a model differs from the measurement values of the quantity being predicted.

$$MAE = \frac{\sum_{i=1}^{n}|(Hic-Him)|}{N} \ldots (10)$$

Mean Absolute Error (MAE) measures how far calculated values are away from the measured values. Hence, another statistical parameter like the coefficient of regression (R), coefficient of determination (R^2) is also calculated.

2. Results and Discussion

Table 1 shows the climatic data for Guranshe, Surkhet, which is based on the above theoretical approach. The values of monthly mean extraterrestrial solar radiation (Ho), monthly mean measured GSR (Hm), the monthly mean of calculated GSR (Hc), the monthly mean of daily hours of bright sunshine (n), the monthly mean of day length (N), the monthly mean of measured clearness index (Hm/Ho), monthly mean of calculated clearness index (Hc/Ho) and the monthly ratio of sunshine hours (n/N).

Table 1: Climatic parameters for Guranshe, Surkhet

Month	Ho	Hm	Hc	a	b	n	N	Hm/Ho	Hc/Ho
Jan	22.08	16.35	13.73	0.29	0.55	6.26	10.4	0.74	0.62
Feb	26.41	16.96	16.46	0.29	0.54	6.65	11.01	0.64	0.62
Mar	31.91	22.31	20.68	0.31	0.51	7.67	11.82	0.7	0.65
Apr	37	21.23	23.64	0.3	0.53	8.03	12.7	0.57	0.64
May	39.95	21.78	25.08	0.29	0.54	8.23	13.43	0.55	0.63
Jun	40.95	16.51	25.34	0.29	0.55	8.23	13.8	0.4	0.62
Jul	40.34	9.79	21.12	0.23	0.67	5.83	13.63	0.24	0.52
Aug	37.95	9.35	19.81	0.23	0.67	5.52	12.99	0.25	0.52
Sep	33.62	10.66	18.94	0.26	0.62	6.05	12.15	0.32	0.56
Oct	28	17.73	17.92	0.3	0.52	7.15	11.27	0.63	0.64
Nov	23	13.37	14.82	0.3	0.52	6.77	10.55	0.58	0.64
Dec	20.69	11.73	12.66	0.28	0.56	5.96	10.2	0.57	0.61
Average	**31.83**	**15.65**	**19.18**	**0.28**	**0.57**	**6.86**			

In Table 1, Ho, Hm, and Hc are in the unit of $MJ/m^2/day$, n and N are in the unit of hours. From table 1, we can say that the value of annual extraterrestrial solar radiation (Ho) found to be 31.83 $MJ/m^2/day$, measured global solar radiation (Hm), calculated global solar radiation (Hc) is found to be 15.65 $MJ/m^2/day$ and 19.18 $MJ/m^2/day$. Annually 6.86 hours of the bright sunshine hour was observed which indicates that the Guranshe, Surkhet is a place where a high possibility of GSR can be obtained which can be the favorite place for solar farming. The value of regression constants a and b in the Angstrom-Prescott model, calculated by using Tiwari and Sangeeta model, are found to be a=0.28 and b=0.57.

Based on the above calculations in Table1, statistical error arises between the calculated and measured value. Table2 shows the analysis between the calculated value and the measured value of the Guranshe, Surkhet of the year 2018.

Table 2: Statistical tools.

RMSE $MJ/m^2/day$	MBE $MJ/m^2/day$	MAE $MJ/m^2/day$	MPE %
5.01	3.69	3.82	-6.94

From Table 2, RMSE is found to be 5.01 $MJ/m^2/day$, which measures how much error is found between the calculated value and the measured value. Similarly, MBE, MAE, and MPE are found to be 3.69 $MJ/m^2/day$, 3.82 $MJ/m^2/day$, and -6.94%, negative value indicates that our estimated data is underestimated. The values in Table 2 show good agreement between the calculated and the measured values of global solar radiation for the year of 2018.

The Seasonal, Monthly, and daily variation of Global Solar Radiation of Guranshe, Surkhet of the year 2018 is shown in Figure 3, Figure 4, and Figure 5:

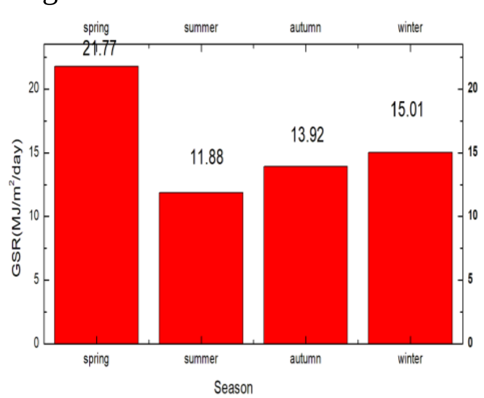

Fig.3: Seasonal variation of GSR.

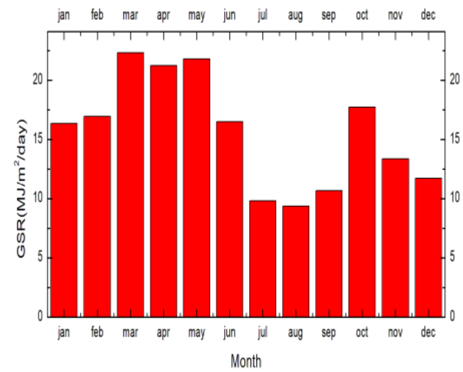

Fig.4: Monthly variation of GSR.

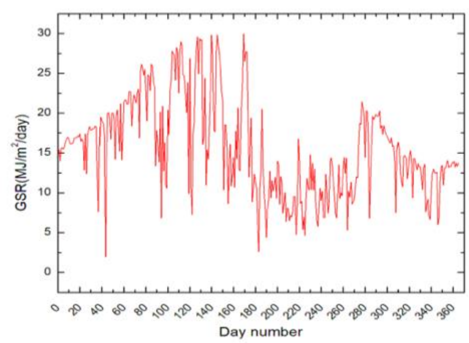

Fig.5: Daily variation of GSR.

The maximum and minimum seasonal global solar radiation are found in the spring and summer season respectively. In the spring season GSR is found to be 21.77 $MJ/m^2/day$ and in the summer season GSR is found to be 11.88 $MJ/m^2/day$ for the year of 2018. The variation in local weather condition is the main reason for such differences. Minimum GSR in the summer season is due to cloudy sky of rainy circumstances (average 9.67 mm per day). The high value of GSR in the spring season, on the other hand, is due to the less cloud, less rainfall, and less solar zenith angle. In the winter season, the more fog, large solar zenith cause lower value of GSR. From the monthly variation of GSR as shown in Figure 4, it is found that the low values of global solar

radiation are found in July, August and September (9.79 MJ/m^2/day, 9.35 MJ/m^2/day, and 10.7 MJ/m^2/day). The high values,
on the other hand, are found in March, April and May (22.3 MJ/m^2/day, 21.2 MJ/m^2/day and 21.8 MJ/m^2/day respectively). The daily variation of GSR is shown in Figure 5, and reveals that the value of GSR is continuously increasing and found a maximum (of value 22.3 MJ/m^2/day) in March. After attending the peck value, the GSR starts decreasing and is found to be a minimum (of 9.35 MJ/m^2/day) in August. It is due to the rainy season where there is high rainfall and relative humidity. The annual average GSR of the year 2018 is found to be 15.65 MJ/m^2/day. The maximum value of global solar radiation suggests that there is a high potential of solar energy in that place.

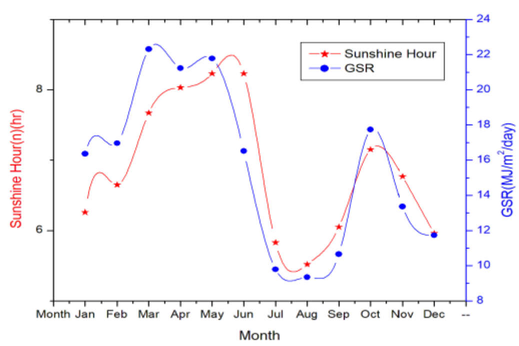

Fig.6: Monthly variation of sunshine hour (red line with stars) and GSR (blue line with circles).

Sunshine hour indicates the sun in the clear sky seen during a certain period usually expressed in an hour. The monthly variation of the estimated sunshine hour of Guranshe, Surkhet is shown in Figure 6, from the above graph we can say that the estimated sunshine hour (n) continuously increases from January to June. It means that the sun shining hour increases and becomes maximum hours (hr.) in April, May, and June i.e. on average 8 hours in a day. After reaching 8hr (with some fluctuations) it starts decreasing which indicates that the sunshine hour changes every day/month due to the solar declination, zenith angle, and other climatological factors. The estimated sunshine hour data indicates that it annually averages to 6.86 hours in a day at Guranshe, Surkhet.

The variation of the measured value of GSR with the estimated sunshine hour is shown in Figure 6. The trend of the GSR and sunshine hour (SSH) is similar, which indicates that the GSR has a direct relation with the SSH. In the starting month, January, sunshine hour and GSR start increasing which is consistent with the theory. After the month of June the trend of GSR and SSH both decrease which is due to the heavy rainfall and high relative humidity. After August they resume increasing and reach to the maximum values in the October. Beyond October the values of SSH and GSR again decrease as per direct relationship between them. The more sunshine hour means the more radiation to the ground, which is generally found in the spring (shown in the graph). Physical phenomenon like scattering and absorption of incoming radiation are also low in a clear sky of the season. The variation of global solar radiation (GSR) with meteorological parameters like air temperature, air pressure, relative humidity, and rainfall is shown in Figure 7, Figure 8 and Figure 9.

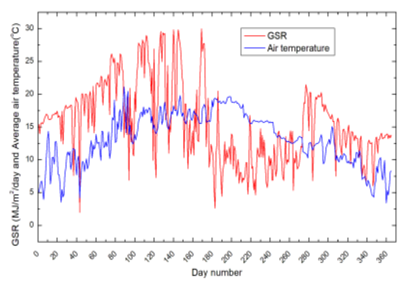

Fig.7: Daily variation of GSR with Average Air Temperature for the year 2018.

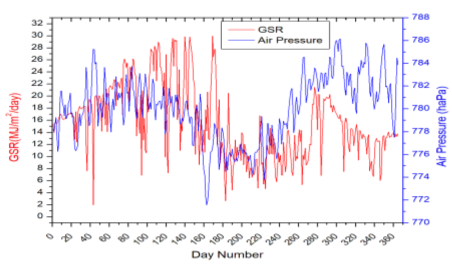

Fig.8: Daily variation of GSR with Air Pressure for the year 2018.

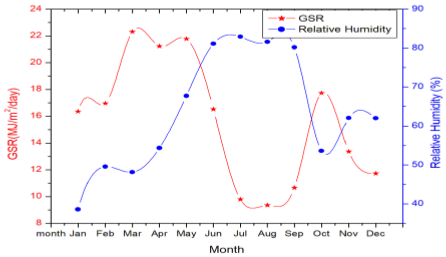

Fig.9: Monthly variation of GSR with Relative Humidity for the year 2018.

Figure 7 shows that there is a strong agreement between the measured global solar radiation and average air temperature. It the beginning of the Figure 7, both air temperature and global solar radiation increase to attain maximum and then both decrease sharply due to the cloudy days, high relative humidity, and high frequency of rainfall in July, August, and September. The annual average air temperature was found to be of 10.82°C in the year 2018.

The daily variation of global solar radiation with air pressure is shown in Figure 8. Air pressure is the pressure exerted by the weight of air in the atmosphere of earth, which depends on the gravitational force. In Figure 8, we see that as the air pressure increases global solar radiation also increases and vice versa which indicates the direct relationship between the air pressure and global solar radiation. The minimum value of air pressure is found in July i.e. 775.747haPa and maximum in October i.e. 783.45haPa. On average 780.747haPa pressure is found in the year of 2018 which is suitable for solar farming.

The monthly variation of GSR with relative humidity is shown in Figure 9. A strong inverse relation is found between global solar radiation and relative humidity. Low relative humidity i.e. 38.59% is found in the winter season due to dry and the presence of less moisture and high relative humidity i.e. 90.50% is found in the summer season due to the presence of lots of water vapor. Water in the air acts as a disturbance of GSR that falls on the ground which decreases the amount of GSR on the surface. The correct level of humidity and GSR are important for professional visitors and tourists in the place. Hence the future energy harvesting project has to consider the effect of vegetation in humidity and vice versa. Rainfall and water vapor in the air are the related quantities and show the similar effects (inverse relation) to GSR. From the beginning of the year i.e. from January, there is low rainfall and GSR is found to be increasing. The increase in rainfall gets accelerated after a certain month i.e. in the rainy season where the average of 9.68 mm of rainfall is found in three months: July, August, and September. The inverse relation between the GSR and rainfall can be understood in terms of cloud; the rainfall requires cloud in the sky and the presence of clouds blocks GSR. However, the rainfall fluctuates within a single month and the reciprocate effect can be seen in GSR. It has been noted that the maximum rainfall and the minimum GSR in August are found as 14.43 mm and 9.34, MJ/m^2/day respectively.

An empirical model: finding coefficient of determination and coefficient of regression:

We have used two models; (i) Angstrom-Prescott, and (ii) Tiwari and Sangeeta model to predict the GSR at that particular place by using correlation coefficients a, b, sunshine hour (n), extraterrestrial radiation (Ho), and day length (N). The value of regression coefficient was found by using Tiwari and Sangeeta model.

$$\frac{H}{Ho} = a + b(\frac{n}{N}) \ldots (1)$$

The left-hand side of this equation is the clearness index ($\frac{H}{Ho}$). The values of a and b are found 0.28 and 0.57 (Table1). The coefficient of determination (R^2) and coefficient of regression (R) are determined from Figure 10 where we show the graph between measured clearness index ($\frac{Hm}{Ho}$) and calculated clearness index ($\frac{Hc}{Ho}$).

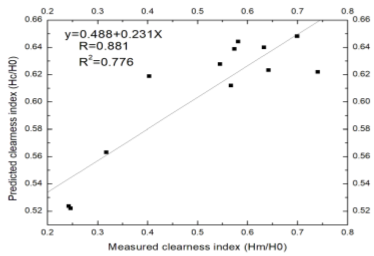

Fig.10: Measured clearness index ($\frac{Hm}{Ho}$) versus calculated clearness index ($\frac{Hc}{Ho}$)

Figure 10 finds the coefficient of regression (R) as 0.881 and the coefficient of determination (R^2) as 0.776. The regression coefficient says us negative or positive correlation between dependent and independent variables. We find positive correlation coefficient from our calculations. This implies that the increase in dependent variable on increasing the independent variables. The coefficient of determination, which lies in between 0 and 1, is also known as the goodness of fit. It tells us how strong the relationship between two variables is. The regression coefficient 0.881 means 88.1% of the dependent variable is predicted from the information of independent variables. Hence the good (high) value of regression coefficient tells us a good prediction of clearness index. For a clearer (less cloudy) day there is high value of the global solar radiation. In the Figure 10, we see high values of the coefficient of regression and coefficient of determination which indicates the high to clearness index in Guranshe, Surkhet (for the year 2018). From the above discussion, we see that the annual average of measured and the calculated/predicted values of GSR are found to be 15.65MJ/m^2/day and 19.18 MJ/m^2/day respectively. Also, the correlation coefficients are found to be a = 0.28 and b = 0.57. The GSR values from our calculations fall in same order of magnitude comparing to the previous studies at different places, like in Lukla(14.51MJ/m^2/day),Kathmandu(13.753 MJ/m^2/day),Pokhara(16.499MJ/m^2/day),Jumla(19.884MJ/m^2/day)andSimikot(16.562MJ/m^2/day) [7].The comparison clearly shows that our calculation for Guranshe agrees the most (within 5.4% of difference) with Pokhara. This is due to similar geological and metrological situation in both the places. All the values (from our calculations and previous study) show the good potential of solar energy technology in those places. The results also inspire the authorities in sub-Himalaya terrain (like Surkhet), inner terai, and also other similar geographical locations of Nepal to promote solar energy harvesting industries like Photovoltaic solar panels, solar water heater, Dye-sensitized solar cells, Energy storage, Rechargeable batteries and other possible applications [16].

3. Conclusions

The measured GSR, calculated GSR and other meteorological parameters affecting GSR were studied by using the available data. The GSR of the year 2018 A.D. at Guranshe, Surkhet was measured at the horizontal surface using a CMP3 pyranometer. On the other hand, GSR and the other empirical constants have been estimated by using numerical models like: Angstrom-Prescott and Tiwari and Sangeeta model. The annual average of measured and the calculated/predicted values of GSR were found to be 15.65MJ/m^2/day (4.35kWh/m^2/day) and 19.18 MJ/m^2/day (5.33kWh/m^2/day) respectively. Also, the correlation coefficients were found to be a=0.28 and b=0.57. The comparison in between the measured and calculated values of GSR were performed by using the methods of

Root Mean Square Error (RMSE), Mean Bias Error (MBE), Mean Absolute Error (MAE), and Mean Percentage Error (MPE). Various metrological parameters like average air temperature, sunshine hour, air pressure, relative humidity were found to be affecting the values of GSR as per established relationship. Our study shows that Gurashe (Surkhet) has similar average GSR value comparing to the other places of Nepal and better agreement is seen with Pokhara due to similar geological/metrological parameters.

Harvesting the solar energy can be helpful for solar farming and mitigating the energy crisis of the places especially where the other sources of energy are hardly accessible. Having high potential of tourist destination, the regularity in energy supply through alternative source can enhance its pace of development in Surkhet and similar territories of Nepal.

Acknowledgment

The authors acknowledge the Department of Hydrology and Meteorology (DHM/GoN), Government of Nepal for providing meteorological data relevant to the study. Special thanks are due to Prof. Dr. K. N. Poudyal, faculty member at IOE, Pulchwk Campus, Tribhuvan University, and Sanjeep Sapkota for useful discussions.

References

[1] J. Ekpe, M. Nnabuchi, Solar Radiation in Onitsha: A Correlation with Average Temperature, Scholarly J. Biotechnol. 1(5) (2012)101-107.

[2] Nepal Electricity Authority, A year in Review (2020).

[3] K. R. Adhikari, Estimation of Globla Solar Radiation for Four Selected Sites in Nepal using Sunshine Hours, Temperature and Relative Humidity, J. Power Energy Eng.1(2013)1-9.

[4] P. Rijal, 95.5 percent of Nepalis have an electricity connection, report says, The Kathmandu Post (dated June-4, 2019).

[5] R. Kumar et al., New Regression model to Estimation Global Solar Radiation using Artificial Neural Network, Adv. Energy Eng. 1 (2013) 66-73.

[6] M. Iqbal, An Introduction to Solar Radiation, Academic Press, (1983).

[7] K. R. Adhikari et al., Solar Energy Potential in Nepal and Global Context, J. Inst. Eng. 9(2013)95-106. https://doi.org/10.3126/jie.v9i1.10675

[8] B.R. Kc, S. Gurung, Estimation of the Daily Global Solar Radiation using RadEst 3.00 Software at Nepalgunj, J. Inst. Eng.12 (2016) 199-209. https://doi.org/10.3126/jie.v12i1.16903

[9] J. Awasthi, K. N. Poudyal, Estimation of Global Solar Radiation using Empirical model on Meteorological Parameters at Simara Airport, Bara, Nepal, J. Inst. Eng. 14 (2018) 143-150 https://doi.org/10.3126/jie.v14i1.20078

[10] C. I. Elekalachi et al., Estimation of Global Solar Radiation from Monthly Mean Sunshine Hour data in some Cities in South Eastern zone of Nigeria, Physics Journal. 2(2016) 96-103.

[11] A Brief Profile of Surkhet District, June, 2014 Kathmandu, Nepal https://studylib.net/doc/6972573/a-brief-profile-of-surkhet-district

[12]http://www.hydrology.gov.np/#/basin/37/image [Photo provided by Department of Hydrology and Meterology]

[13] Manual (2008), CMP6 Pyranometer, Kipp and Zonen

[14] M. H. Abd el-wahed, R. L. Snyder, Calculating Sunshine hours and Reference Evapotranspiration in Arid Regions when Solar Radiation data are limited, Irrigation and Draining, 64 (2015) 419-425 https://doi.org/10.1002/ird.1920

[15] M.H. Soulouknga et al., Determination of a Suitable Solar Radiation Model for the Sites of Chad, Energy power Eng.(2017) **9**703-722.DOI: 10.4236/epe.2017.912045

[16] Z.Abdin et al., Solar Energy Harvesting with the Application of Nanotechnology, Renew. Sust. Energ. Rev.(2013)26737-8.