

Research Article

Solar Radiation, Air Temperature, Relative Humidity, and Dew Point Study: Damak, Jhapa, Nepal

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Received 7 August 2019; Revised 20 October 2019; Accepted 21 November 2019; Published 11 December 2019

Academic Editor: Leonardo Sandrolini

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Monitoring and prediction of the climatic phenomenon are of keen interest in recent years because it has great influence in the lives of people and their environments. This paper is aimed at reporting the variation of daily and monthly solar radiation, air temperature, relative humidity (RH), and dew point over the year of 2013 based on the data obtained from the weather station situated in Damak, Nepal. The result shows that on a clear day, the variation of solar radiation and RH follows the Gaussian function in which the first one has an upward trend and the second one has a downward trend. However, the change in air temperature satisfies the sine function. The dew point temperature shows somewhat complex behavior. Monthly variation of solar radiation, air temperature, and dew point shows a similar pattern, lower at winter and higher in summer. Maximum solar radiation (331 Wm^{-2}) was observed in May and minimum (170 Wm^{-2}) in December. Air temperature and dew point had the highest value from June to September nearly at 29°C and 25°C , respectively. The lowest value of the relative humidity (55.4%) in April indicates the driest month of the year. Dew point was also calculated from the actual readings of air temperature and relative humidity using the online calculator, and the calculated value showed the exact linear relationship with the observed value. The diurnal and nocturnal temperature of each month showed that temperature difference was relatively lower (less than 10°C) at summer rather than in winter.

1. Introduction

Monitoring and prediction of the climatic phenomenon have developed over the years; as a result, wide knowledge and information have been gathered that have helped to understand and to predict it. More importantly, climatic change has a great influence on the lives of people and their environments [1]. It is influenced by the location latitude, elevation, and proximity to water bodies. Solar radiation is one of the important parameters to study climate change, environmental pollution, crop production, food industry, and hydrology [2]. Even for the design of a solar energy conversion system, it requires precise knowledge of the availability of global solar radiation at the location of interest [3–5]. Hence, the total solar radiation potential will be a key factor for designing and predicting the performance of solar energy equipment [6–8].

Temperature is a measure of the thermal state of matter and represents the degree of hotness or coldness of a body. It is a widely measured variable to determine the change in weather because it influences or controls other elements of the weather, such as the dew point temperature, precipitation, humidity, clouds, and atmospheric pressure [9]. The impacts of changes in temperature extremes on natural ecosystems and on human infrastructure are now widely recognized as being more important than changes in average values. Climatic variability is also important for the human perception of climate [10].

The relative humidity and dew point temperature are widely used indicators of the amount of moisture in the air [11]. The relative humidity is a sensitive parameter that impacts the physical performance of electrical devices, metals, agro-food, and biological items. It also measures the thermal discomfort of the individuals [12]. There are

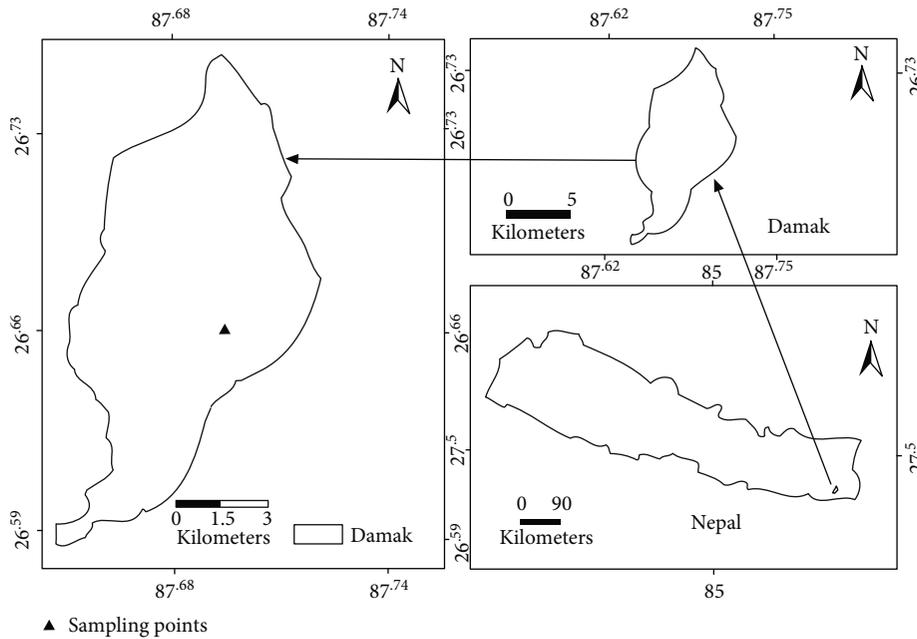


FIGURE 1: Location of the study area in the map of Nepal.

numerous factors such as dew point temperature, ambient temperature, and solar radiation that can combine to influence relative humidity [13]. The relative humidity more than 80% always creates discomfort due to the characteristics of deliquescent of the salt in the surface of the skin [14], and 100% humidity leads to muggy conditions.

The dew point temperature is the temperature where water vapor in the atmosphere will just condense into liquid water at the same rate at which it evaporates. It can be therefore stated that the partial vapor pressure is equal to the partial saturation vapor pressure at the dew point temperature. Dew point temperature is preferred by meteorologists over relative humidity as an indicator of human comfort [15] and also used in forecasting the rain, frost, and fog formation as well as the probability of thunderstorms [16]. Dew point greater than 60°C at lower atmosphere gives the probability of intense thunderstorms [17]. Many studies on recent temperature and solar radiation trends have been carried out all over the world. However, studies of temperature and other parameters at more local scales are also needed to be given the fact that broad-scale analyses may mask considerable spatial and temporal variation in climatic trends [18].

The ground-based weather station is a very reliable and authentic source to generate the meteorological data for climatic research, and still, it is used to collect the data from different stations for the study of spatial and temporal variation. Available literatures show that few and limited studies have been conducted in eastern Nepal. Probably it is due to inadequacy of existing solar energy data or lack of research culture among the researcher [19]. The present study is aimed at explaining the daily and monthly variation of some meteorological parameters such as solar radiation, air temperature, relative humidity, and dew point in Damak, the eastern city of Nepal.

2. Materials and Methods

2.1. Study Area. Damak is situated between $26^{\circ}35'21.28''\text{N}$ to $26^{\circ}44'58.71''\text{N}$ latitude and $87^{\circ}39'9.40''\text{E}$ to $87^{\circ}43'10.32''\text{E}$ longitude in the southeastern Terai region of Nepal with 130 m in elevation from sea level. It has a subtropical monsoon climate with summer temperatures ranging from 32°C to 35°C , winter temperatures ranging from 8°C to 15°C , and an average annual rainfall of 270 mm [20]. The weather station is situated in the premise of Damak Multiple Campus which had been established in 2012. The location of the weather station is shown in Figure 1.

2.2. Description of Sensors. A solar radiation sensor (pyranometer) was used to determine the solar radiation for short-wave radiation which has a spectral range of 305-2800 nm and radiation range of $0\text{-}2000\text{ W/m}^2$ with 5% accuracy. It had +1 repeatability, cosine response at 750 zenith angle +10%, and cosine response at 450 zenith angle +4% whose sensitivity was custom calibrated to exactly $5.00\text{ Wm}^{-2}/\mu\text{V}$ and operating environment of -40 to 55°C and 0 to 100% RH. Similarly, another sensor was the air temperature and relative humidity sensor to determine the temperature and relative humidity. It was a digital sensor in which the temperature ranges from -40 to 123.8°C with $\pm 0.1^{\circ}\text{C}$ at 5 to 40°C and has a resolution of 0.01°C typical. It also measures 100% range of relative humidity with $\pm 2\%$ at 20 to 80% accuracy and resolution of 0.5% RH typical and has long-term stability type $< 1\%$ RH/year with repeatability of $\pm 0.1\%$ having digital output. The relative sensor measures variance in the capacitance change of a one micron thick dielectric polymer layer. This film absorbs water molecules through metal electrode and causes a capacitance change that is proportional to relative humidity. All these sensors were manufactured by Virtual Electronics Company, India.

2.3. Data Acquisition System. In the weather station, there are various sensors attached to detect various climatic parameters, and the weather station with different sensors is shown in Figure 2. All sensors are attached with this data logger for the collection of real-time data automatically, and data logger is adjusted within half an hour resolution for one year. The microcontroller converts the analog signals from these sensors to digital format. In order to collect data from the weather station, we use the instrument Data Shuttle which is a pocket-sized device that can be used to download and transport the data from the weather station to a computer, allowing the instrument to stay in place for continuous monitoring/recording. The downloaded file is saved in .xlsx (Microsoft Excel) format.

3. Results and Discussions

The instantaneous intensity of global solar radiation, air temperature, relative humidity, and dew point measured on 09 February 2013 has been depicted in Figure 3. On a clear and sunny day, diurnal variation of solar radiation exhibited a noon maximum, decreased with the decrease of solar altitude and became least (zero) in the morning and evening. However, due to the presence of the cloud in the path of the sunlight, some irregularities were found in the trend. The maximum value of solar radiation recorded on that day was 696 W/m^2 exactly at noon. The variation of solar radiation during 24 hours in the clear sky day always followed the Gaussian fit [21] in which adjusted R^2 value was 0.9899. Again, the increasing or decreasing trend of solar radiation is almost symmetrical on a sunny day.

The variation of the daily air temperature is shown in Figure 3(b). The highest air temperature occurred in the afternoon (1:00-2:00 PM), and it showed that even in the afternoon, the air kept net absorbing heat. However, afternoon, air temperature gradually decreased all night and indeed occurred the least value during the early morning. Nonlinear fit showed that daily variation of the air temperature followed the sine function (adj. $R^2 = 0.944$) [22] rather than Gaussian fit (adj. $R^2 = 0.932$), and it is shown by the fitted curve of red color. Just after the sunrise and just before the sunset, the air temperature is rising and dropping the fastest. Again, the time required for air temperature rising from the lowest temperature to the highest temperature is around 8 hours, but the time required for air temperature going down from the highest to the lowest is more than 15 hours. It is due to the fact that light is easily absorbed by the earth surface and converts into heat energy, but once the heat is generated, it is not easily escaped from the atmosphere because the atmosphere acts as a blanket and blocks the outgoing radiation.

The relative humidity is inversely related to the air temperature. If temperature increases, the relative humidity decreases, and vice versa. On 9th of February, relative humidity varied from 35 to 90% during 24 hours, and it is depicted in Figure 3(c). As the temperature increased, the RH gradually decreased and attained the lowest value at around 3 pm. Thereafter, RH rapidly increased and attained the highest value with small fluctuation during the whole night. The



FIGURE 2: Weather station with some components: (1) wind direction sensor, (2) wind speed sensor, (3) pyranometer, (4) air temperature and RH sensor, and (5) data logger.

variation of the RH can be explained as follows: at nighttime, mass of water vapors present in the atmosphere is relatively high, but at higher temperature (daytime), evaporation rate is high enough to convert water into water vapor and mass of the water vapor present in the atmosphere of given volume is relatively low; as a result, relative humidity is also low. The variation of air temperature followed the sine function whereas the relative humidity followed the Gaussian fit [23] in which the R -adjusted value is 0.9607.

Dew point temperature is the function of RH and air temperature. Its variation during 24 hours is shown in Figure 3(d). When the air temperature varied from 10 to 26°C , the dew point changed from 8 to 12°C . During the morning and evening, the dew point was found to have the lowest value. However, on the day and nighttime, its value was relatively high.

Air temperature and relative humidity are two different climatic parameters in which RH is greatly affected by the air temperature. For the given mass of the water vapor present in the atmosphere, the increase in air temperature always reduces the RH. Sometimes, RH is also affected by the other climatic phenomenon like rainfall, wind flow, and cloudy day [24], and their overall effect on the RH can be observed in Figure 4(c). In January, the coldest month of the year, RH was relatively higher and its value rapidly fell down to reach the lowest value at the month of April (55.4%) representing the driest month of the year. The RH, afterward, gradually increased and became nearly constant during the rainy seasons. The maximum relative humidity that was recorded during that period was around 80%. After a slight fall in November, it again rose to reach 75% in December. It is obvious that combination of high temperature and humidity is inimical to human health especially on people who work outside and responsible for the cases of increased heatstroke [25].

The sunshine hour is an important factor to determine solar radiation and air temperature. In Kathmandu valley, the sunshine hour is higher (7 hours/day) in the

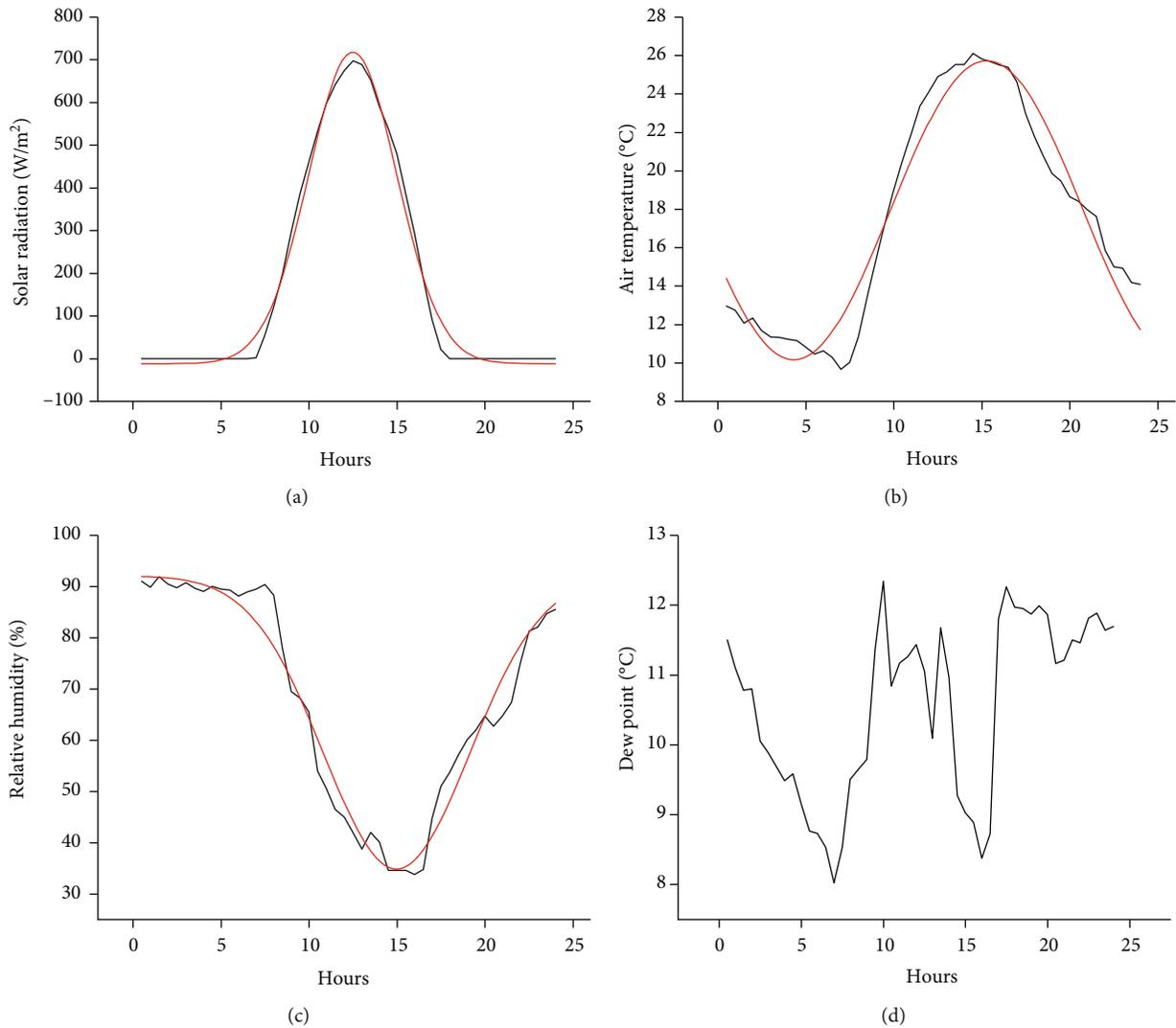


FIGURE 3: Daily variation of solar radiation, air temperature, RH, and dew point on the 9th of Feb. 2013.

winter, premonsoon, and postmonsoon season and least (5 hours/day) in the monsoon season [26]. The data of the Kathmandu valley represents the whole part of Nepal because it is situated in the middle part of Nepal.

The variation of the air temperature and solar radiation is displayed in Figures 4(a) and 4(b). The research conducted by Regmi and Adhikary [26] and Poudyal et al. [27] also reported the similar pattern of monthly variation of solar radiation in Kathmandu and Pokhara valley as we observed in Damak. In winter especially in January, February, November, and December, the sunshine hour was higher but the earth received the least solar radiation due to an oblique incident of the sunlight and optically thick low cloud [28]; as a result, the temperature was also low. April and May represent the premonsoon period. The highest sunshine hour, clear and sunny day, made the earth surface to receive the maximum solar radiation during premonsoon. June, July, August, and September represent the monsoon period in Nepal. During that period, the earth received lesser

solar radiation as compared to the premonsoon period. It was primarily caused by least sunshine hour, high precipitation, and cloud [29]. However, air temperature remains constant during those periods.

The variation of average monthly dew point is exhibited in Figure 4(d). The variation of dew point followed the same pattern as that of air temperature and changed from 10 $^{\circ}\text{C}$ to 25 $^{\circ}\text{C}$. Dew point increased from the lowest value at the month of January and attained the highest value during the month of June, July, August, and September. Finally, it fell sharply to attain the second minimum values of 13.65 $^{\circ}\text{C}$. As we know, dew point depends upon both relative humidity and air temperature but the result discloses that dew point is greatly controlled by air temperature rather than relative humidity.

The monthly observed value of RH obtained from the weather station and the online calculation is demonstrated in Figure 5. Both observed and online calculated value are highly correlated with each other. The online calculator

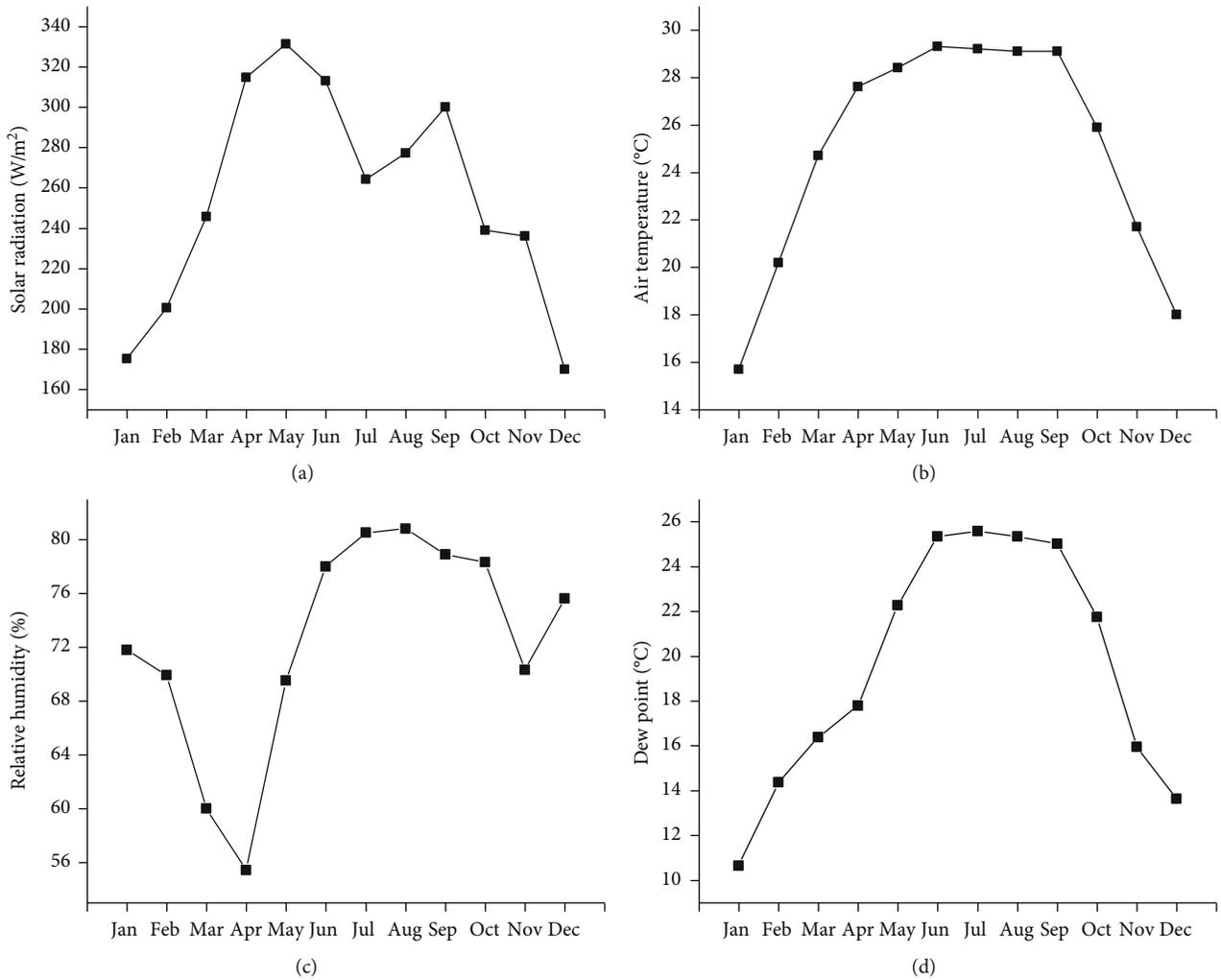


FIGURE 4: Monthly variation of solar radiation, air temperature, RH, and dew point in 2013.

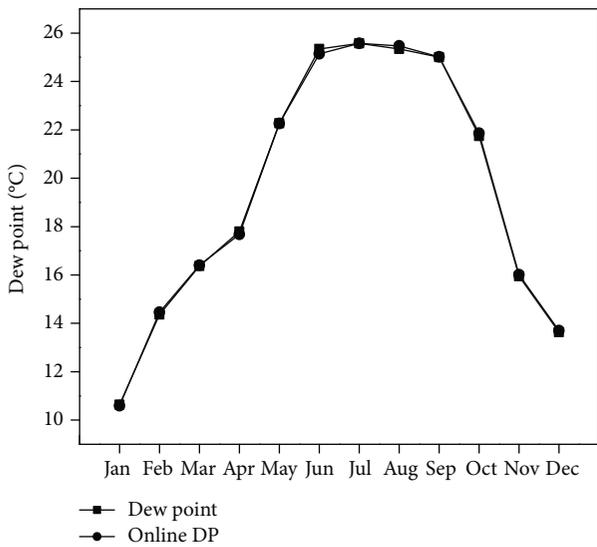


FIGURE 5: Observed and online calculated value of dew point.

estimates the dew point on the input data of air temperature and relative humidity using the mathematical relation given in Equation (1) [11].

$$T_{\text{dew point}} = \frac{b((aT/b + T) + \ln \text{RH})}{a - ((aT/b + T) + \ln \text{RH})}, \quad (1)$$

where $a = 17.27$, $b = 237.7$, and $\text{RH} = 0 - 1$.

The higher the value of adjusted R^2 , the better is the fitness of data points. The value of $r = 0.9998$ and its adj. $R^2 = 0.9985$ of the observed and online calculated value of dew point tells us that 99.8% data gives the exact fit of a linear relationship. From the statistical point of view, we can say that the quality of the measured data is relevant.

The maximum and minimum temperature of each month is estimated by taking the maximum and minimum temperature of each day and calculating the average value over the period of one month. Figure 6 presents the significant variation of the temperature difference between the highest and the lowest value for the year 2013. During the month of May, June, July, August, September, and October,

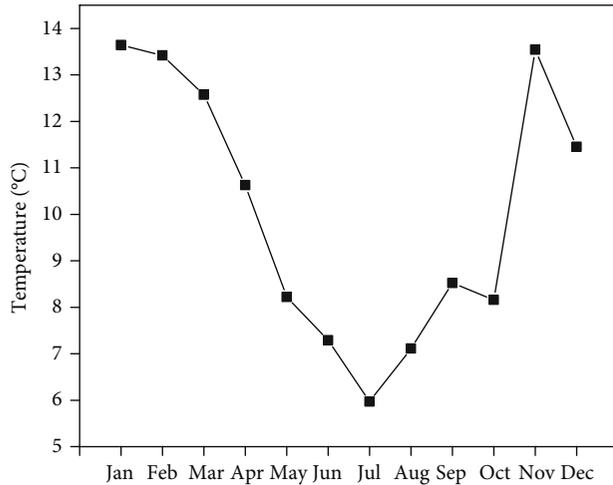


FIGURE 6: Monthly temperature difference between the maximum and the minimum value.

temperature difference went down below 10°C , and these months especially represented the moderate climatic condition due to rain and cloud in summer. The lowest temperature difference was observed in July to have only 5.97°C . However, in winter especially the first four months and last two months, the difference in diurnal and nocturnal temperature was higher than 10°C . It is due to the fact that during that period, day time temperature is normal but night time temperature is extremely low; as a result, these months represent the extreme climatic condition. Overall, in Damak, we receive the moderate as well as extreme climatic condition throughout the year.

The correlation matrix of Table 1 demonstrated that there was a strong correlation of air temperature and dew point with solar radiation with a significant level of less than 1%. It is due to the fact that air temperature is directly related to the global solar radiation. So, increase in solar radiation increases the air temperature. Similarly, dew point also depends on the air temperature and relative humidity, and it is clear from Equation (1). Hence, it is also clear that dew point is significantly correlated with solar radiation.

4. Conclusion

From the statistical point of view, it is concluded that in a clear and sunny day, the variation of solar radiation and relative humidity follows the Gaussian distribution but the air temperature variation is governed by a sine function. The monthly variation pattern of solar radiation, air temperature, and dew point demonstrates that they have the highest value at summer and lowest in winter. The solar radiation data can also be used to estimate the solar energy potential at Damak to promote solar photovoltaic cells. Correlation matrix shows that the dew point is significantly correlated with air temperature rather than relative humidity. Statistically, observed data from the weather station and calculated data from the online calculator are highly correlated ($\text{adj. } R^2 = 0.9985$) and give the relevancy of the measured data. The temperature difference between the maximum and the

TABLE 1: Correlation matrix of climatic parameters.

	Solar radiation	Air temperature	RH	Dew point
Solar radiation	1			
Air temperature	0.90557	1		
RH	-0.07948	0.17727	1	
Dew point	0.76008	0.93209	0.52082	1

minimum value showed that low difference (less than 10°C) was recorded in summer whereas in winter more than 10°C . The lowest value of the relative humidity (55.4%) in April is an indication of the driest month of the year.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

I would like to thank Caritas Nepal for providing the financial support to install the Automatic Weather Station in the premise of Damak Multiple Campus and Mr. Basudev Kafle and Mohan Sangroula for initiating and delivering fruitful dialogue with Caritas Nepal to install it in campus.

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