The Prediction of Solar Energy in Supporting Green Energy at Bongkasa Pertiwi, Sangeh, Mengwi, Pelaga and Pangsan

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Abstract: Bongkasa Pertiwi, Sangeh, Mengwi, Pelaga and Pangsan are five villages in Badung Regency, Bali Province. Badung Regency Tourism Office plans these five villages as tourism villages that are supported by green energy. For this purpose, we conduct a study on solar energy potential for solar cells using data from the Prediction of Worldwide Energy Resources (POWER) at the average latitude and longitude position of the five village offices location, i.e., -8.44209 lat and 115.21381 lon. In addition, we collected the data of all-sky insolation incidents on a horizontal surface (kW-hr/square meter/day) for this position from 2010 to 2019. As stated in Table 2-4, the result shows that the sixth-order polynomial equation and its coefficients can predict the maximum, mean, and minimum solar energy value in these areas. Furthermore, the adjusted r-square of the insolation fitness equation has a value of more than 90 percent.

1 INTRODUCTION

Several researchers have studied solar energy in Bali Province in several locations, such as Nusa Penida, Kayubihi, Denpasar, and Badung Regency, focused on sunlight intensity and required battery capacity comparison of simulation results with the actual production of electrical energy and also solar energy modeling.

Research on solar energy in Nusa Penida, a small island located at 8°44'4" south latitude and 115°32'2" east longitude in Klungkung Regency, shows that the area gets light intensity average of 5.34 kWh/m^2/day with a wind speed average of 4.4 m/s (Manik, Wijaya, & Juliandhy, 2014). In Kutampi Village, Nusa Penida, a solar power plant supplies a base transceiver station (BTS) load of 174.66 kWh that requires 45 panels with a total battery capacity of 3,800 Ah and a whole battery of 16 units (Indrawan & Hartati, 2013). Solar-powered street lighting in Nusa Penida had also been analyzed and summarized about the causes of battery damage were due to disproportionate to the load capacity requirements and because the battery has been old (Wiguna, Ariastina, & Kumara, 2012).

The study found at Pemecutan Kaja Village, Denpasar City, Bali Province that the average daily energy produced by the solar panel is 23.59 kWh, yielding energy at IDR 7,766/kWh. Experiment to clean filters of the plant reduced daily energy consumption from 8.84 kWh to 3.05 kWh or 65% (Arimbawa, Kumara, & Hartati, 2016).

In Kayubihi, Bangli Regency, a 1 MWp solar power plant has been built and connected to the electricity network. The comparative study of simulation results with the actual production of electrical energy shows a difference of 32.3% (Setiawan, Kumara, & Sukerayasa, 2014).

In Denpasar City, the capital of Bali Province, research on solar energy at elementary school no. 5, located in Pedungan area, with a roof angle of 30.96° produces an energy potential of 3214.6 kWh, lower

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than the optimal angle of 15° that make the immense potential value of 3407 kWh (Kristiawan, Kumara, & Giriantari, 2019). Statistically, our research modeled the electrical characteristics of the 150-Watt peak solar panel in Denpasar using Boltzmann sigmoid function with a good fit (Sapteka et al., 2018). Furthermore, the lighting systems with 150-Watt peak solar panel in Denpasar shows that the maximum received wattage is 0.76 kW/day in October based on NASA data (Narottama, Amerta Yasa, Suwardana, Sapteka, & Priambodo, 2018).

In Badung Regency, the hybrid solar power plant for the parking area of Cipta Karya Building, Office of Highways and Irrigation of Badung Regency has been planned, which works automatically controlled by the inverter system that produces 148.274 kW, which is equal to 30% of the electrical energy consumption in the building of 2.310 MWh (Duka, Setiawan, & Weking, 2018).

This paper discusses the solar energy projections in Bongkasa Pertiwi, Sangeh, Mengwi, Pelaga, and Pangsan areas that other researchers have never studied. The research aims to support this area to become tourism villages supported by green energy.

2 METHODOLOGY

2.1 Determining the Average Location

As shown in Table 1, we should select the average location by determining the midpoint of latitude and longitude of Bongkasa Pertiwi, Sangeh, Mengwi, Pelaga, and Pangsan Government Office. The small blue square in Figure 1 shows the locations of government offices in these villages. It is fixed that the average site is -8.44209 lat and 115.21381 lon.

Table 1: Location of village government office.

Area	Latitude	Longitude
Bongkasa Pertiwi	-8.4697	115.2386
Sangeh	-8.4874	115.2112
Mengwi	-8.54429	115.17041
Pelaga	-8.2958	115.227
Pangsan	-8.4133	115.2217
Average	-8.44209	115.21381

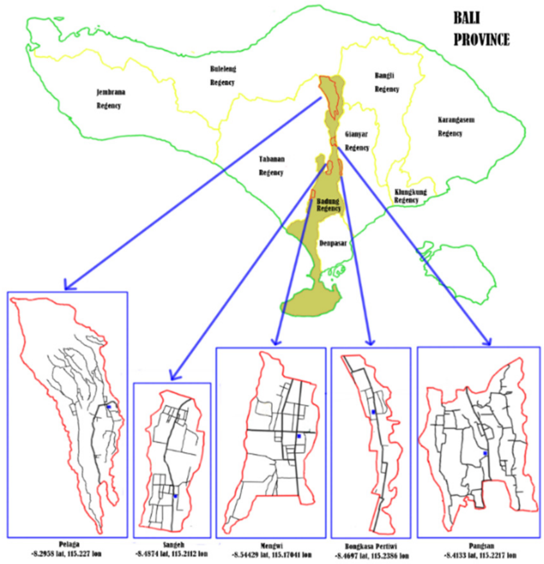

Figure 1: Location of government office.

2.2 Collecting the Data

We collect the all-sky insolation incident on horizontal surface data from the Prediction Of Worldwide Energy Resources (POWER) at the average latitude and longitude of the five village offices, i.e., -8.44209 lat and 115.21381 lon. This data is collected from 2010 to 2019 in kW-hr/square meter/day.

2.3 Analysing the Data

First, we analyze the data by finding the monthly maximum, mean and minimum values of all-sky insolation incidents on a POWER's horizontal surface data. The next step is calculating the fittest order of polynomial equations and their coefficients. The equations are used as prediction of insolation value at Bongkasa Pertiwi, Sangeh, Mengwi, Pelaga and Pangsan. Last step is determining the statistic of maximum, mean and minimum equations to ensure the prediction.

3 RESULT AND DISCUSSION

3.1 Result

Based on the determination of the average location of the five village offices at Table I, the all-sky insolation incidents on a horizontal surface data was collected from the Prediction Of Worldwide Energy

Resources (POWER) at the average latitude and longitude position of the five village offices location, i.e., -8.44209 lat and 115.21381 lon. This data is collected from 2010 to 2019 in kW-hr/square meter/day as shown in Figure 2 to Figure 11.

In 2010, insolation incidents on a horizontal surface had a maximum value of 5.9 kW-hr/m^2/day in March. It increases from January to March, then decreases until May with a minimum value of 4.3 kW-hr/m^2/day. The value climbs from May to November but drops in December, as shown in Fig. 2.

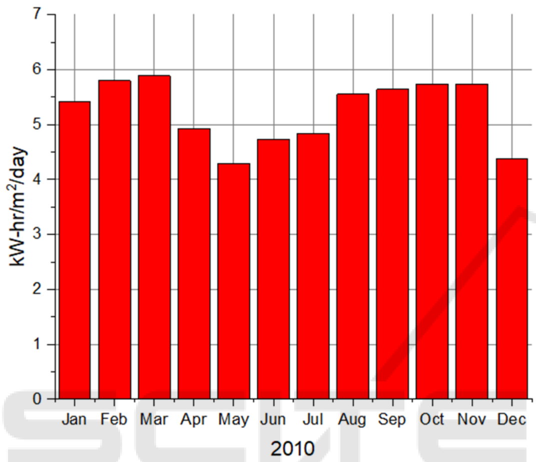

Figure 2: Insolation incident on a horizontal surface in 2010.

In 2011, an insolation incident on a horizontal surface had a maximum value of 6.3 kW-hr/m^2/day in October and a minimum value of 4.8 kW-hr/m^2/day in April, as shown in Figure 3.

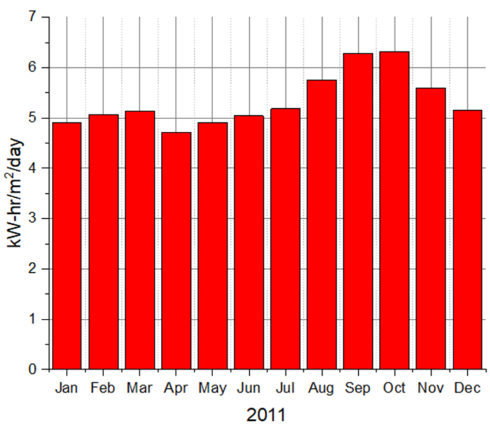

Figure 3: Insolation incident on a horizontal surface in 2011.

In 2012, insolation incidents on a horizontal surface had a maximum value of 6.5 kW-hr/m^2/day in October and a minimum of 4.4 kW-hr/m^2/day in January. However, it fluctuates from January to July. For example, the value climbs from July to October but decreases until December, as shown in Figure 4.

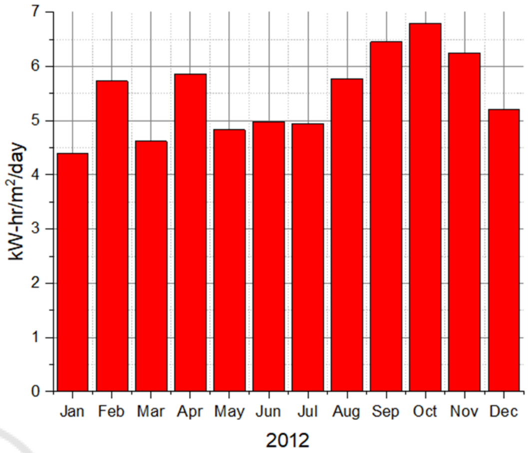

Figure 4: Insolation incident on a horizontal surface in 2012.

In October 2013, an insolation incident on a horizontal surface had a maximum value of 6.7 kW-hr/m^2/day. It increases from January to March and then decreases to June, reaching a minimum value of 4.3 kW-hr/m^2/day. Because of the sun's movement from northern to southern solstice, the insolation increases from June to October but then goes down until December, as shown in Figure 5.

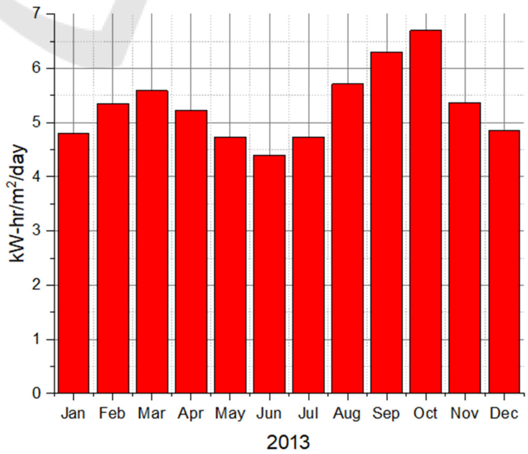

Figure 5: Insolation incident on a horizontal surface in 2013.

The insolation incident on a horizontal surface in 2014 experienced a similar pattern with 2013. It has a maximum value of 6.9 kW-hr/m^2/day in October. It increases from January to March and then decreases to July, where it reaches a minimum value of 4.8 kW-hr/m^2/day. The sun's shifting from northern to southern solstice causes the insolation to increase from July to October but then declines until December, as shown in Figure 6.

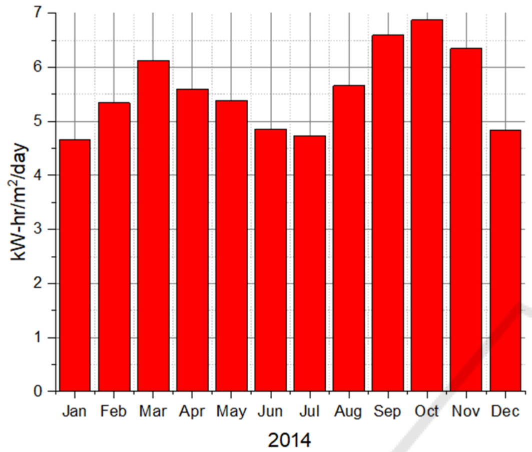

Figure 6: Insolation incident on a horizontal surface in 2014.

In 2015, the insolation incidents on a horizontal surface increased from January to February, and then it decreased until April with a minimum value of 4.9 kW-hr/m^2/day. It fluctuates in May and June before increases to reach its maximum value of 6.8 kW-hr/m^2/day in October then goes down until December, as shown in Figure 7.

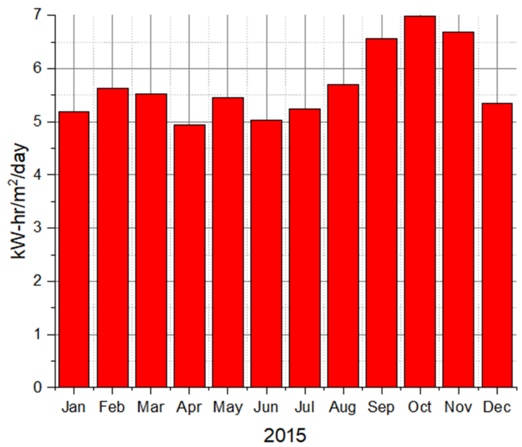

Figure 7: Insolation incident on a horizontal surface in 2015.

In 2016, the insolation incident on a horizontal surface fluctuated from January to March. It reached a minimum value of 4.6 kW-hr/m^2/day in February. From March to June, it decreases linearly and then climbs from June to September. Finally, it reaches a maximum value of 6.8 kW-hr/m^2/day in September, then drops until December, as shown in Figure 8.

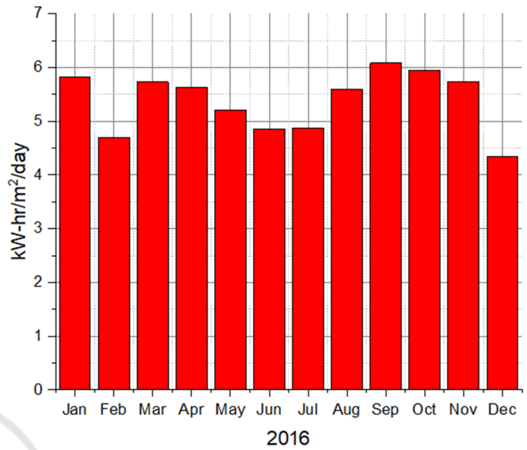

Figure 8: Insolation incident on a horizontal surface in 2016.

In 2017, insolation incidents on a horizontal surface fluctuated from January to May and then declined until June. From June to September, it increases and reaches a maximum value of 6.3 kW-hr/m^2/day in September and October, then decreases sharply in November and December to reach a minimum value of 4.7 kW-hr/m^2/day, as shown in Figure 9.

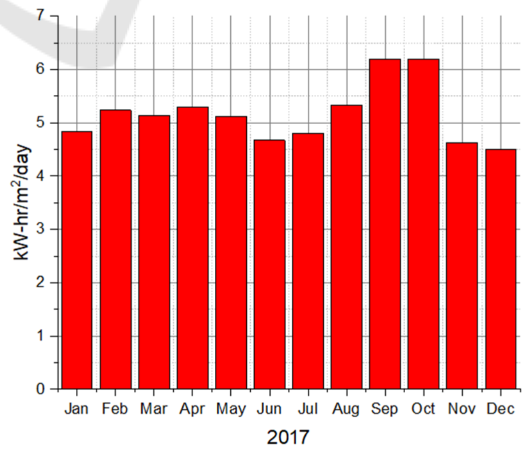

Figure 9: Insolation incident on a horizontal surface in 2017.

In January 2018, an insolation incident on a horizontal surface experienced a minimum value of 4.4 kW-hr/m^2/day. From January to April, it increases and then goes down until June. Furthermore, it gradually increases from June to October where it reaches maximum value of 6.8 kW-hr/m^2/day. As shown in Figure 10, the insolation decreases linearly from October to December.

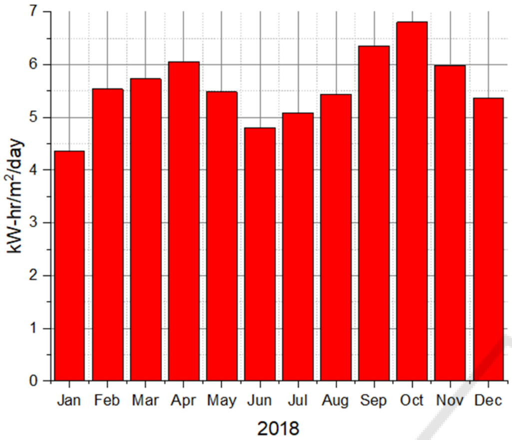

Figure 10: Insolation incident on a horizontal surface in 2018.

In 2019, insolation value had higher condition than in 2018, i.e., it reached a minimum value of 5.0 kW-hr/m^2/day in January and maximum value of 7.0 kW-hr/m^2/day in October. It fluctuates from January to March and increases linearly to May. Insolation value fluctuation occurs again from May to June before it climbs to reach maximum value in October, as shown in Figure 11. The insolation value decreases from October to December.

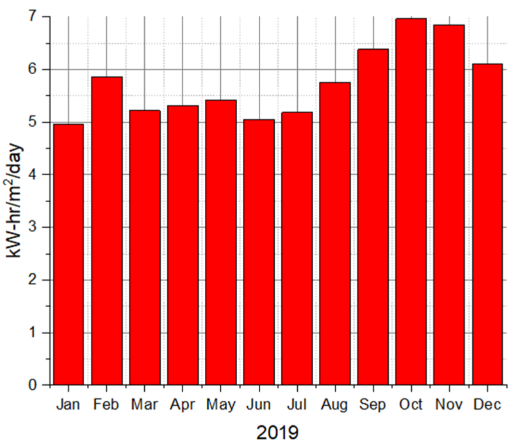

Figure 11: Insolation incident on a horizontal surface in 2019.

3.2 Discussion

After collecting the data, we analyze it by finding the monthly maximum, mean and minimum value of all-sky insolation incidents on a horizontal surface from 2010 to 2019. As shown in Figure 12, The red line plots the maximum value, where it reaches the lowest value of 5.0 kW-hr/m^2/day in June and the highest value of 7.0 kW-hr/m^2/day in October. The blue line plots the minimum value, where it reaches the lowest value of 4.5 kW-hr/m^2/day in May and the highest value of 5.7 kW-hr/m^2/day in October. Meanwhile, the yellow line plots the mean value, where it reaches the lowest value of 4.8 kW-hr/m^2/day in June and the highest value of 6.5 kW-hr/m^2/day in October.

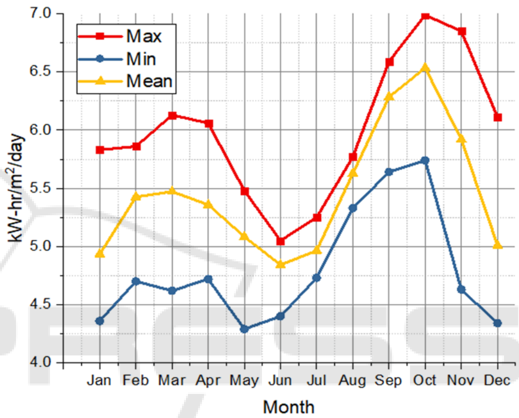

Figure 12: Max, min and mean value of insolation from 2010 to 2019.

Using the maximum, mean and minimum insolation data as shown in Figure 12, we deliver a 6th order polynomial as stated in Eq. (1) to predict the solar energy in Bongkasa Pertiwi, Sangeh, Mengwi, Pelaga and Pangsan area.

$$y = g + B_1x^1 + B_2x^2 + B_3x^3 + B_4x^4 + B_5x^5 + B_6x^6 \quad (1)$$

Here, y is the value of insulation (kW-hr/m^2/day), and x is the number of months. Table 2-4 shows the coefficient values in Eq. (1) for the polynomial fit of maximum, mean, and minimum equations.

Table 2: Coefficient of maximum insolation fitness.

Coefficient	Value
g	8.47318 ± 0.46565
B_1	-5.37383 ± 0.77834
B_2	3.67557 ± 0.44693
B_3	-1.08975 ± 0.11881
B_4	0.15343 ± 0.01595
B_5	-0.01011 ± 0.00105
B_6	$2.51225\times10^{-4} \pm 2.68386\times10^{-5}$

Table 3: Coefficient of mean insolation fitness.

Coefficient	Value
g	5.70982 ± 0.69508
B_1	-2.16013 ± 1.16184
B_2	1.98487 ± 0.66713
B_3	-0.6786 ± 0.17735
B_4	0.10404 ± 0.02381
B_5	-0.00725 ± 0.00157
B_6	$1.87173\times10^{-4} \pm 4.00622\times10^{-5}$

Table 4: Coefficient of minimum insolation fitness.

Coefficient	Value
g	5.5175 ± 1.19266
B_1	-2.74317 ± 1.99356
B_2	2.25739 ± 1.14471
B_3	-0.76468 ± 0.3043
B_4	0.12081 ± 0.04085
B_5	-0.00882 ± 0.00269
B_6	$2.404\times10^{-4} \pm 6.87413\times10^{-5}$

Figure 13-15 draws the graphs of this fitness using Eq. (1) and the coefficient for the polynomial fit of max, mean, and min values as stated in Table 2 – 4.

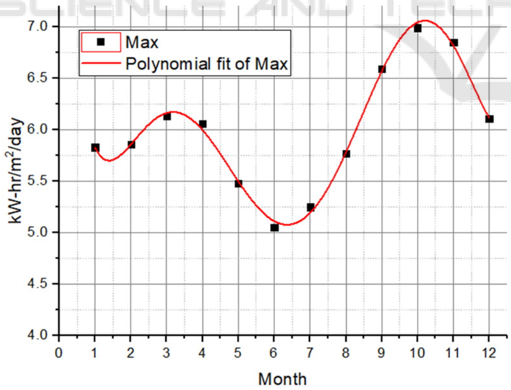

Figure 13: Maximum value of insolation and its 6th order polynomial fit.

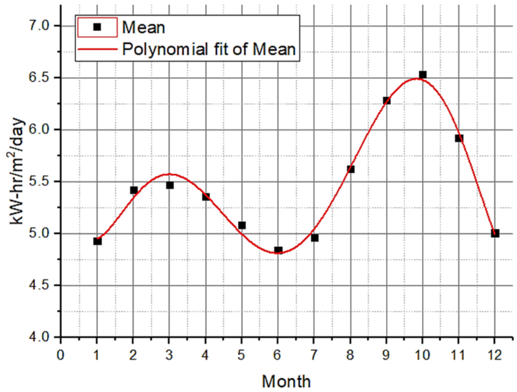

Figure 14: Mean value of insolation and its 6th order polynomial fit.

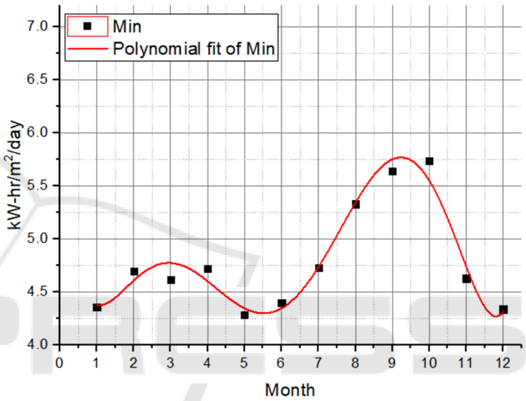

Figure 15: Minimum value of insolation and its 6th order polynomial fit.

All the polynomial fit equations show the statistic value of adjusted r-square more than 90%, as stated in Table 5-7.

Table 5: Statistic of maximum insolation fitness.

Parameter	Value
number of points	12
degree of freedom	5
residual sum of squares	0.01731
r-square	0.99558
adj. r-square	0.99028

Table 6: Statistic of mean insolation fitness.

Parameter	Value
number of points	12
degree of freedom	5
residual sum of squares	0.03858
r-square	0.98844
adj. r-square	0.97457

Table 7: Statistic of minimum insolation fitness.

Parameter	Value
number of points	12
degree of freedom	5
residual sum of squares	0.11357
r-square	0.95910
adj. r-square	0.91003

Therefore, Eq. (1) is fit to predict the maximum, mean, and minimum insolation value in supporting energy independence at Bongkasa Pertiwi, Sangeh, Mengwi, Pelaga, and Pangsan area.

4 CONCLUSIONS

The 6th order polynomial equation, as stated in Eq. (1), can predict the solar energy in supporting green energy at Bongkasa Pertiwi, Sangeh, Mengwi, Pelaga, and Pangsan area. We can use it to forecast the maximum, mean and minimum insolation values in these areas by using coefficients as stated in Table 2 – 4. The statistic shows that all of the adjusted r-square of insolation fitness values are more than 90%.

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