Journal of Infrastructure Planning and Engineering (JIPE)

Journal homepage: https://ejournal.warmadewa.ac.id/index.php/jipe

NASA Power's: an alternative rainfall data resources for hydrology research and planning activities in Bali Island, Indonesia

I Gusti Ngurah Putu Dharmayasa[1,2,*], Cathleen Ariella Simatupang[2], Doni Marisi Sinaga[3]

[1]*Department of Civil Engineering, Faculty of Engineering and Informatics, Universitas Pendidikan Nasional, Denpasar, 80224, Indonesia*
[2]*Department of Civil and Environmental Engineering, Faculty of Engineering, Mahidol University, Salaya, 73170, Thailand*
[3]*International Program in Hazardous Substance and Environmental Management, Graduate School, Chulalongkorn University, Bangkok, 10330, Thailand*
[*]ngurah.dharmayasa@gmail.com

Received on 24 February 2022, accepted on 27 March 2022, published on 18 April 2022

ABSTRACT

Rainfall data is critical for planning and research in the field of hydrology. Rainfall data must be available continuously, which means it must be recorded continuously. This recording will continue since numerous projects in the field of hydrology require continuous rainfall data. Although rainfall data are collected and recorded daily, some stations frequently have insufficient rainfall records, particularly in developing countries such as Bali, Indonesia. These issues may impair the quality of rainfall data, resulting in inaccuracies in the analysis results. To address this issue, we need a reliable source of rainfall data, one of which is NASA Power, which provides rainfall data for free. NASA Power rainfall data is then compared to observed rainfall data. The comparison of the two rainfalls is measured by a statistical parameter, namely the correlation coefficient. Based on the comparison between lowland and highland areas, the average daily rainfall from NASA Power tends to be lower than the average daily rainfall from observation stations. Meanwhile, from the correlation coefficient value (r) of the comparison of rainfall observations and NASA Power, a considerably high correlation coefficient value (> 0.7) was observed. Thus, it can be suggested that the rainfall data from NASA Power for hydrology research and planning activities in Bali Island, Indonesia.

Keywords: Bali Island; NASA Power; rainfall; rainfall comparison

1 Introduction

The amount of rainwater that falls in a given area over a given time can be referred to as rainfall or precipitation [1]. Rainfall data is extremely important in activities relating to hydrological planning and research, as well as in other fields of study such as in the field of hydrology, as it is used in the design of water structures, drainage, irrigation, and flood mitigation plans. Rainfall data must be available continuously, which necessitates the need for it to be recorded on an ongoing basis. This recording is still being done because of various hydrological studies that require continuous rainfall data [2], as well as other reasons. The greater the number of rain stations, the greater the amount of detail in the recorded rainfall data [3].

Although rainfall data are collected and recorded every day, often, the rainfall records by some stations are inadequate, especially in developing countries such as Bali, Indonesia. Rainfall data is extremely sensitive to being lost owing to a variety of factors, including faulty instruments, erroneous measurements, and station relocation. The presence of outliers in rainfall data is also influenced by the temporal and spatial variability of rainfall readings. These issues may compromise the quality of rainfall data, resulting in inaccuracy in analysis results. [4].

Research on the comparison of rainfall from satellites to observed rainfall in Bali has been carried out with various rainfall data sets including rainfall from IMERG [5], CMORPH25, CMORPH8, TRMM, and PERSIANN [6, 7], and GSMaP, IMERG, and CHIRPS [8]. However, research related to the evaluation of rainfall from NASA Power in Bali has never been carried out.

In research by [7] stated that daily rainfall data from CMORPH25, CMORPH8, TRMM, and PERSIANN on daily rainfall observations on the island of Bali obtained low accuracy. Other work [6] compared rainfall from the TRMM satellite model to daily-monthly rainfall data from rainfall stations in Bali. From this study, it was found that rainfall data from satellites tended to be lower than rainfall data from observation stations. However, rainfall data has a fairly good correlation for monthly data, but has a low correlation for daily data. Moreover in [5] evaluated five years of the Integrated Multi-Satellite Retrievals (IMERG) for the period April 2014-April 2019 which was performed over Bali Island, Indonesia, and compared with the observed rainfall data. The study's findings revealed that the IMERG rainfall data were lower than actual rainfall data. IMERG data were very accurate on monthly rainfall data and had a reasonable correlation with daily rainfall data, according to statistical calculations.

Based on previous research, not all rainfall data from satellites can be a solution in overcoming the limitations of observational rainfall. A reliable source of rainfall data is required an alternative rainfall data to resolve this issue and can be obtained for free from NASA Power [9].

NASA's POWER (Prediction of Worldwide Energy Resource) data, with a grid resolution of one-half arc degree longitude by one-half arc degree latitude, is publicly available for download via a web interface. The NASA Power project was started with the goal of improving the present SSE (Surface Meteorology and Solar Energy) data collection as well as creating new data sets from new satellite systems and forecast modeling data [10].

It has been demonstrated that NASA Power's satellite-based products and models are accurate enough to provide reliable weather and solar resource data in areas where surface measurements are sparse or non-existent [11].

2 Data and Methods

This study was conducted at Bali Island, Indonesia (08°03'40" - 08°50'48"S latitude, and 114°25'53" - 115°42'40" E longitude) [12]. Bali covers an area of 5,780.06 km^2, is divided into nine regencies [12], and surrounded by small islands, including Penida Island, Lembongan Island, and Ceningan Island in the south, and Menjangan Island in the north [13]. Bali has a tropical climate and is influenced by monsoonal rainfall patterns. The island is dominated by mountains in the middle of the island, with the dominant lowlands in the southern part of the island (Figure 1). As opposed to narrow lowlands in the north [13].

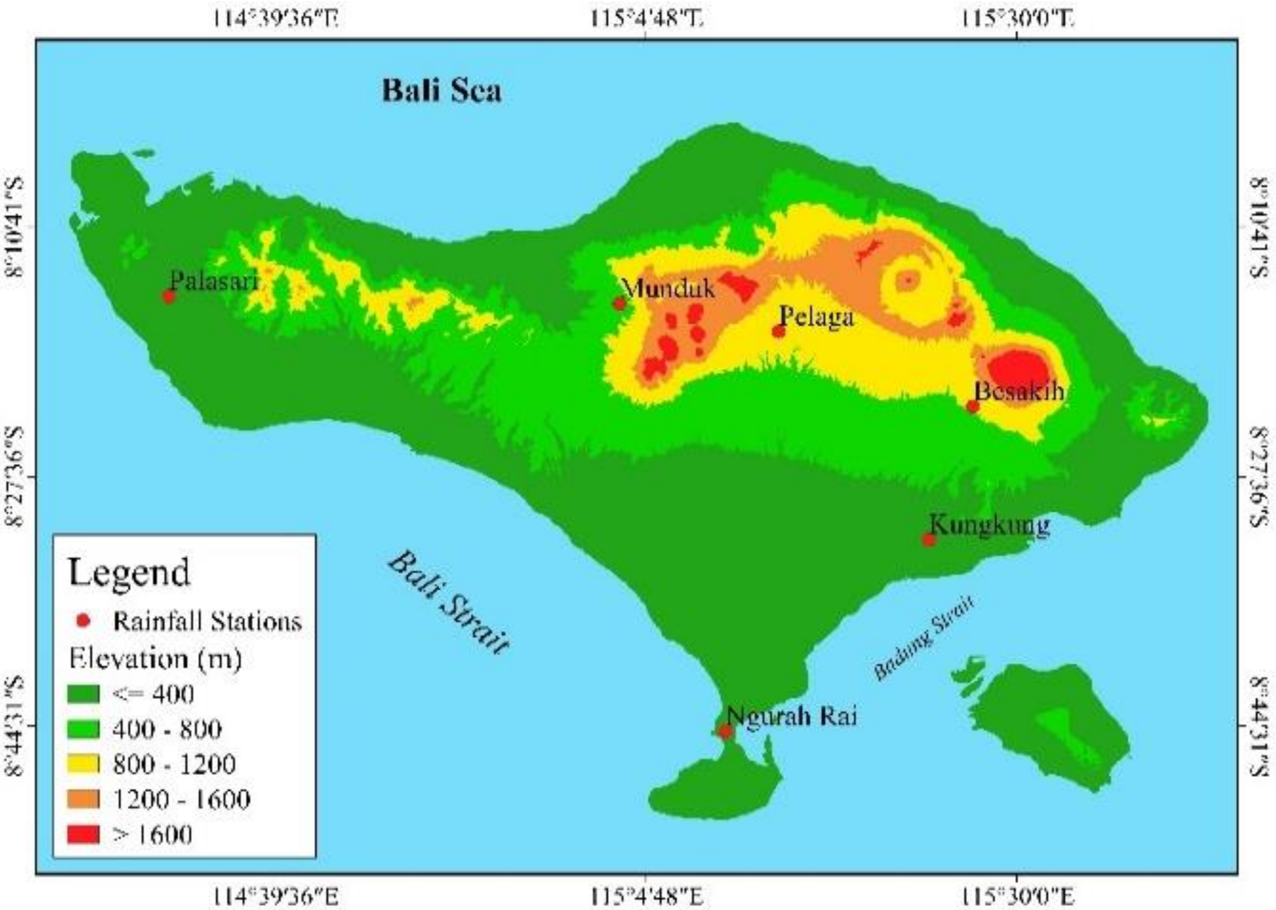

Figure 1. Study Area with the location of each rainfall station

The altitude of the station located in the study area represents the location in the highland and lowland areas (see Table 1). Besakih, Pelaga, and Munduk are the three stations in the highlands (> 700 m above sea level). While Palasari, Ngurah Rai, and Munduk are the stations that represent the lower elevations in the area.

Table 1. Elevation and coordinates of the location of the rainfall station

Stations	Elevation (m)	Latitude	Longitude
Palasari	72	08° 15' 20" S	114° 32' 26" E
Besakih	900	08° 22' 49" S	115° 26' 47" E
Pelaga	788	08° 17' 44" S	115° 13' 36" E
Ngurah Rai	3	08° 44′ 52″ S	115° 10′ 08″ E
Kungkung	93	08° 31' 51" S	115° 24' 17" E
Munduk	750	08° 15' 51" S	115° 03' 02" E

Rainfall analysis was done by comparing the amount of rainfall that was recorded at six different places in Bali with the rainfall that was provided by NASA Power. The Rainfall data from NASA Power were obtained at https://power.larc.nasa.gov/data-access-viewer/. Through this site, important data related to climate can be accessed. These data include long-term climatological mean estimates of meteorological quantities and surface solar energy fluxes [14].

In 2003, the POWER project was initiated as a result of the Surface Meteorology and Solar Energy projects. The initial POWER project included an SSE component and added two new datasets applicable to the architectural and agricultural industries, to continuously improve and expand the focus parameters included in each section of POWER [14].

The evaluation of the rainfall from NASA Power on the observed rainfall was carried out through statistical parameters. The coefficient correlation (r) was compared following the previous studies [15, 16].

The coefficient of correlation results explains the observation and predictor models. Correlation values range from -1 to 1, as shown at Table 2, are an index of the degree of the linear relationship between observed and simulated data [17, 18]. If the value of R = 0 then there is no relationship between the observed data and the simulation. Moreover, a value of R = 1 or -1 indicates a negative or positive relationship. In Table 2 is explained the level of correlation between the two variables [19].

By statistically comparing the rainfall data collected from the NASA Power with the rainfall data observed in this study, it is possible to determine the correlation between the two sets of data. Thus, the rainfall data collected from NASA Power can be recommended to be used as an alternative data resource in planning hydrology research in Bali Island.

Table 2. Correlation value between two variables

r	Meaning of correlation value
0	no correlation
> 0-0.25	very weak correlation
> 0.25-0.5	moderate correlation
> 0.5-0.75	strong correlation
> 0.75-0.99	very strong correlation
> 0.99-1	perfect correlation

3 Results and Discussions

This study used 10-year data collected from six rainfall stations in Bali from 1991 to 2000, for the rainfall analysis. The data was then compared to the precipitation data obtained from NASA Power for the respective location during the same period. Figures 2–7 show the comparison of rainfall at each station during 1991 – 2000.

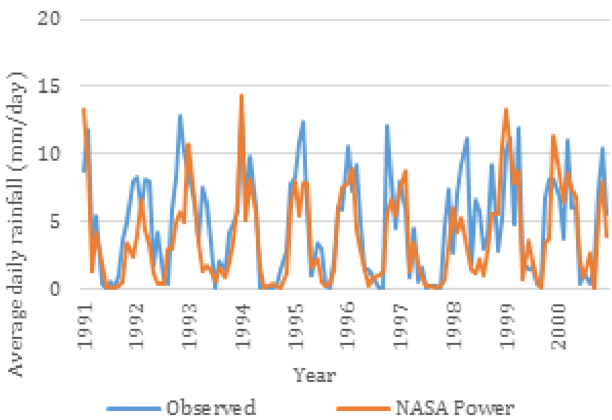

Figure 2. The comparison of average daily rainfall at Palasari station to NASA Power between 1990 and 2000

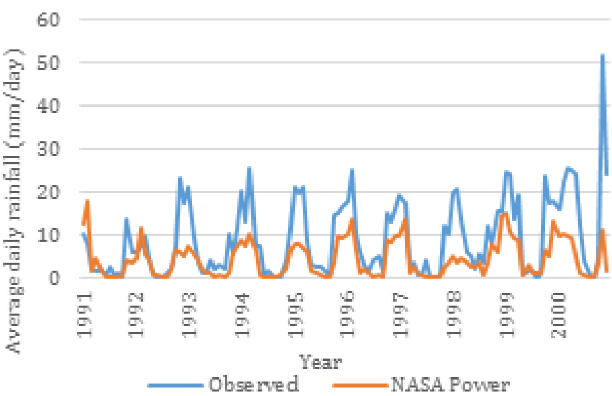

Figure 3. The comparison of average daily rainfall at Besakih station to NASA Power between 1991 and 2000

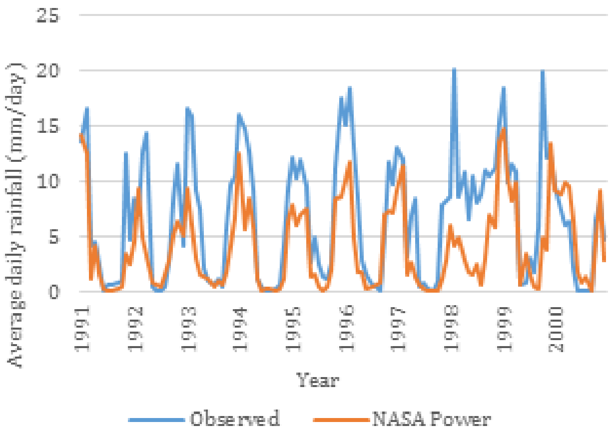

Figure 4. The comparison of average daily rainfall at Pelaga station to NASA Power between 1991 and 2000

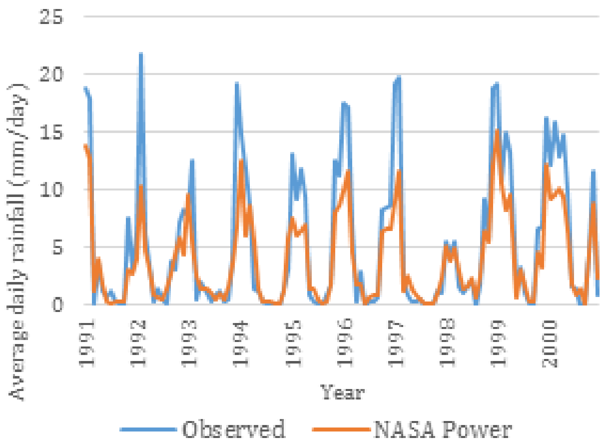

Figure 5. The comparison of average daily rainfall at Ngurah Rai station to NASA Power between 1991 and 2000

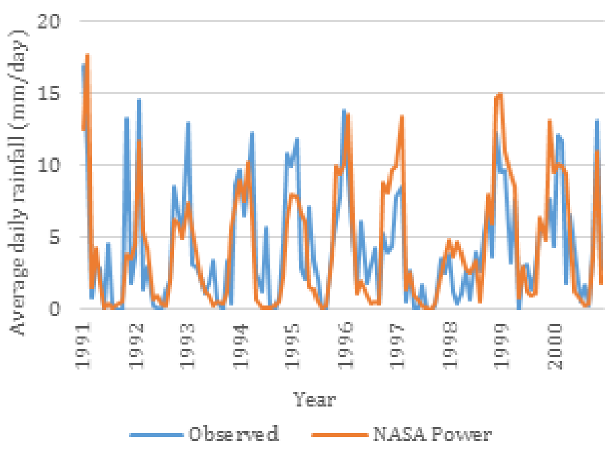

Figure 6. The comparison of average daily rainfall at Klungkung station to NASA Power between 1991 and 2000

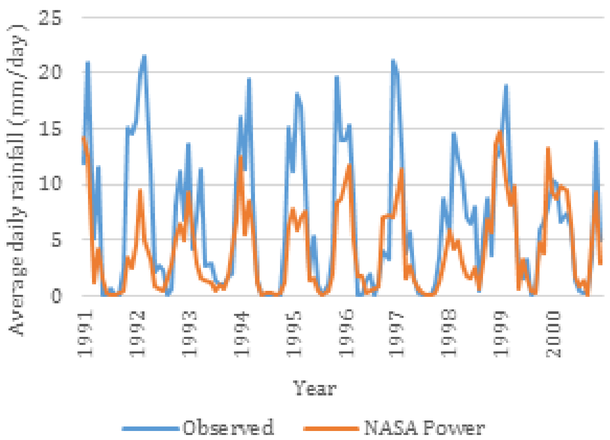

Figure 7. The comparison of average daily rainfall at Munduk station to NASA Power between 1991 and 2000

From Figures 2-7, the variety of rainfall from the two data resources can be observed. From Figure 3, 4, and 7, it is suggested that the rainfall measured at stations located at highlands (> 700 m above sea level) by NASA Power is lower than that measured by an observation station. On the other hand, as shown in Figures 2, 5 and 6, NASA Power's rainfall tends to be in line with observed rainfall at lowlands (<700 m above sea level).

This trend can also be observed from Table 3 and Figure 8 which summarizes the annual rainfall in the highlands (>700 m above sea level).

Table 3. The comparison of annual rainfall from observation stations and NASA Power on highlands during the period 1991 - 2000

Year	Observed	NASA Power
1991	1930	1278
1992	2561	1384
1993	2171	1123
1994	2401	1291
1995	3209	1588
1996	2814	1723
1997	1918	980
1998	3544	1690
1999	3336	2200
2000	3298	1958

From Table 3 and Figure 8 above, it can be observed that the NASA Power's rainfall tends to be lower than the observed rainfall for lowlands (< 700 m above sea level).

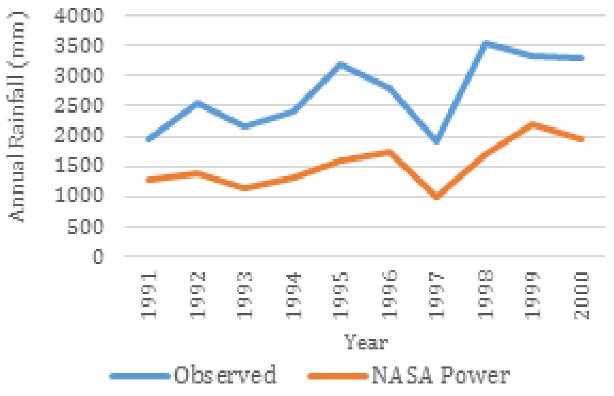

Figure 8. The comparison graph of annual rainfall from highland observation stations and NASA Power during the period 1991 - 2000

However, from Table 4 and Figure 9, the results suggested that the NASA Power's annual rainfall value is very close to the observed value in the lowlands (< 700 m above sea level), particularly in 1996, 1997, and 1998.

Table 4. The comparison of annual rainfall from observation stations and NASA Power on lowlands during the period 1991 - 2000

Year	Observed	NASA Power
1991	1564	1174
1992	1849	1305
1993	1459	1136
1994	1551	1305
1995	1888	1546
1996	1938	1617
1997	1064	937
1998	1735	1588
1999	2211	2122
2000	2119	1903

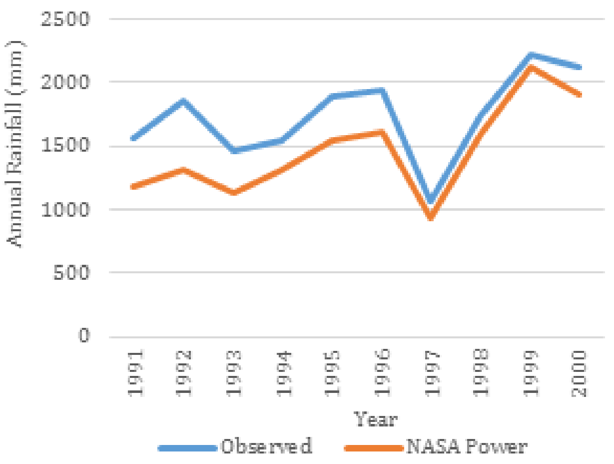

Figure 9. The comparison graph of annual rainfall from lowlands observation stations and NASA Power during the period 1991 – 2000

Meanwhile, the average annual rainfall in the lowlands and highlands can be seen in Table 5 and Figure 10. From Table 5 and Figure 10, the results suggested that the NASA Power's annual rainfall value is lower than that measured by an observation station.

Table 5. Comparison of annual rainfall data from observation stations and NASA Power during the period 1991 - 2000.

Year	Observed	NASA Power
1991	1747	1226
1992	2205	1345
1993	1815	1129
1994	1976	1298
1995	2548	1567
1996	2376	1670
1997	1491	959
1998	2640	1639
1999	2774	2161
2000	2708	1931

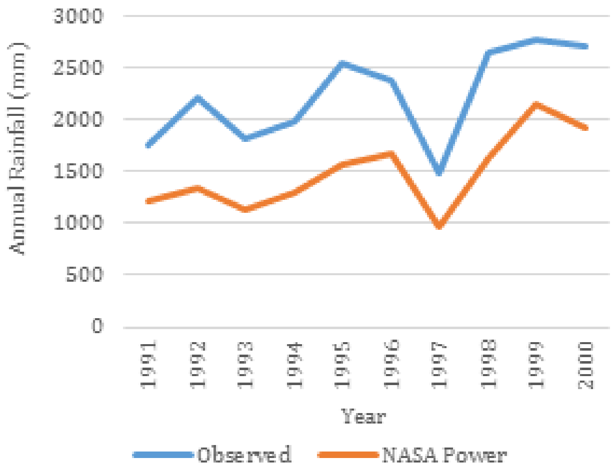

Figure 10. The comparison graph of annual rainfall from observation stations and NASA Power during the period 1991 -2000

Statistical analysis can be performed on the data above to determine the relationship between observed rainfall and NASA Power. Table 6 illustrates the relationship between observed rainfall and NASA Power. According to the Table 6, the average daily rainfall values of NASA Power in the highlands with the observed rainfall stations have the correlation value range between 0.72 and 0.76. The highest correlation values 0.76 for Pelaga station and the lowest 0.72 for Besakih station. While the correlation values range from 0.76 to 0.94 for lowland areas. The lowest correlation value is for Palasari station which is 0.76 and the highest value is 0.94 at Ngurah Rai station. These conditions were in accordance with the results of research in several regions in Indonesia which obtained a correlation value of > 0.7 as a result of a comparison between satellite rainfall data and observational rainfall data [20][21][22]. The rainfall correlations were higher in the lowlands compared to the highlands [22].

Table 6. The correlation between the average of observed daily rainfall and the average of daily rainfall of NASA Power during the period 1991 - 2000

No	Stations	r
1	Palasari	0.76
2	Besakih	0.72
3	Pelaga	0.76
4	Ngurah Rai	0.94
5	Kungkung	0.77
6	Munduk	0.74

4 Conclusion

Based on the correlation coefficient (r) it can be concluded that the observed rainfall from several locations on the island of Bali and NASA Power has a high correlation value. This condition can be seen from the correlation coefficient (r) which is between 0.72 – 0.94. In the lowlands (< 700 m above sea level) the correlation value is higher than in the highlands (> 700 m above sea level).

Rainfall from NASA Power can be utilized as a credible alternative resource if rainfall data is not available for hydrology research and planning operations on Bali Island, based on a high correlation coefficient (> 0.7).

Acknowledgement

The authors are grateful for the rainfall data given by the NASA Langley Research Center (LaRC) POWER Project as part of the NASA Earth Science/Applied Science Program. The Meteorology, Climatology, and Geophysical Agency of the Republic of Indonesia also contributed data from various rainfall observation stations on Bali.

References.

[1] F. A. Muhshi, "Curah Hujan: Pengertian, Klasifikasi, Pengukuran, Dan Alat Ukur." *Forester Act*, January 25, 2022. [Online]. Available: https://foresteract.com/curah-hujan/ [Accessed February 20, 2022].

[2] F. Prawaka, A. Zakaria, and S. Tugiono, "Analisis Data Curah Hujan yang Hilang Dengan Menggunakan Metode Normal Ratio, Inversed Square Distance, dan Cara Rata-Rata Aljabar (Studi Kasus Curah Hujan Beberapa Stasiun Hujan Daerah Bandar Lampung)," *Jurnal Rekayasa Sipil dan Desain*, vol. 4, no. 3, pp. 397-406, Sep. 2016.

[3] A. Izmi, and M. P. Hadi, "Efisiensi jumlah stasiun hujan untuk analisis hujan tahunan di provinsi Jawa Tengah dan Daerah Istimewa Yogyakarta," *Jurnal Bumi Indonesia*, vol. 5, no. 1, Feb. 2016.

[4] S. N. Z. A. Burhanuddin, S. M. Deni, and N. M. Ramli, "Geometric median for missing rainfall data imputation," in *AIP Conference Proceedings*, vol. 1643, no. 1, pp. 113-119. Feb. 2015.

[5] I. W. A. Yuda, R. Prasetia, A. R. As-syakur, T. Osawa, and M. Nagai, "An assessment of IMERG rainfall products over Bali at multiple time scale." in *E3s web of conferences,* EDP Sciences, vol. 153, no. 2, p. 02001, Jan. 2020.

[6] A. R. As-Syakur, T. Tanaka, R. Prasetia, I. K. Swardika and I. W. Kasa, "Comparison of TRMM multisatellite precipitation analysis (TMPA) products and daily-monthly gauge data over Bali," *International Journal of Remote Sensing,* vol. 32, no. 24, pp. 8969-8982, Oct. 2011.

[7] N. Rahmawati, and M. W. Lubczynski, "Validation of satellite daily rainfall estimates in the complex terrain of Bali Island, Indonesia," *Theor. Appl. Climatol*, vol. 134, pp. 513–532, Nov. 2018.

[8] C.-Y. Liu, P. Aryastana, G.-R. Liu, and W.-R. Huang, "Assessment of satellite precipitation product estimates over Bali Island," *Atmospheric Research*, vol. 244, p. 105032, Nov. 2020, doi: 10.1016/j.atmosres.2020.105032.

[9] Photovoltaic-Software.com, "How to get solar radiation and climate data (precipitaton, temperature, wind, insolation...) anywhere in the world free from NASA database?," *Photovoltaic*. 2022. [Online]. Available: https://photovoltaic-software.com/principle-ressources/how-get-solar-radiation-data-world-free [Accessed February 21, 2022].

[10] NASA Langley Research Center, "The POWER Project," *NASA,* 2021. [Online]. Available: https://power.larc.nasa.gov/ [Accessed February 20, 2022].

[11] V. N. Dike, T. C, Chineke, O. K. Nwofor, and U. K. Okoro, "Evaluation of horizontal surface solar radiation levels in southern Nigeria". *Journal of renewable and sustainable energy*, vol. 3, no. 2, p. 023101, Mar. 2011.

[12] Badan Pusat Statistik Provinsi Bali, "Area and Geographic Location of Bali Island and Its Regency/Municipality," *Badan Pusat Statistik Provinsi Bali*, 2020. [Online]. Available: https://bali.bps.go.id/statictable/2018/04/10/47/luas-wilayah-dan-letak-geografis-pulau-bali-dan-kabupaten-kota.html [Accessed February 20, 2022].

[13] Perkim.id, "Profil Perumahan Dan Kawasan Permukiman Provinsi Bali," *perkim.id*, October 8, 2021 [Online] Available:https://perkim.id/pofil-pkp/profil-provinsi/profil-perumahan-dan-kawasan-permukiman-provinsi-bali/ [Accessed February 20, 2022].

[14] A. H. Sparks, "Nasapower: a NASA POWER global meteorology, surface solar energy and climatology data client for R," *Journal of Open Source Software*, vol. 3, no. 30, p. 1035, Oct. 2018.

[15] J. Pérez-Sánchez, J. Senent-Aparicio, F. Segura-Méndez, D. Pulido-Velazquez, and R. Srinivasan, "Evaluating Hydrological Models for Deriving Water Resources in Peninsular Spain," *Sustainability*, vol. 11, no. 10, May 2019.

[16] A. A. Murphy, "The Coeficient of Correlation and Determination as Measures of Perfomance in Forecast Verification," *Weather and forecasting*, vol. 10, no. 4, pp. 681-688, 1995.

[17] S. Rustiana, B. N. Ruchjana, A. S. Abdullah, E. Hermawan, S. B. Sipayung, I. G. N. M. Jaya, and Krismianto, "Rainfall prediction of Cimanuk watershed regions with canonical correlation analysis (CCA)," *Journal of Physics: Conference Series*, vol. 893, no. 1, 2017.

[18] D. N. Moriasi, , J. G. Arnold, M. W. V. Liew, R. L. Bingner, R. D. Harmel, and T. L. Veith, "Model Evaluation Guidlines for Systematic Qualification of Accuracy in Watershed Simulations," *American Society of Agricultural and Biological Engineers,* vol. 50, no. 3, pp. 885 - 900, Mar. 2007.

[19] M. Burhanuddin, "Koefisien Korelasi, Signifikansi, dan Determinasi," *Muhammad Burhanuddin*. January 30, 2021 [Online]. Available: https://alvinburhani.wordpress.com/2012/06/28/koefisien-korelasi-signifikansi-determinasi/ [Accessed February 20, 2022].

[20] D. W. Pratiwi, J. Sujono, and A. P. Rahardjo, 2017. "*Evaluasi Data Hujan Satelit untuk Prediksi Data Hujan Pengamatan Menggunakan Cross Correlation*," Prosiding Semnastek. November 1 – 2, 2017, Jakarta, 2017.

[21] R. S. Linggasari, and Y. L. Handayani, “Perbandingan penggunaan data hujan satelit dan data hujan lapangan untuk pemodelan hidrologi hujan-aliran (studi kasus DAS Tapung Kiri),” *JOM FTEKNIK*, vol.2, no. 2, pp. 1-10, Oct. 2015.
[22] Giarno, M. P. Hadi, S. Suprayogi, and S. H. Murti, “Distribution of accuracy of TRMM daily rainfall in Makassar Strait,” *Forum Geografi*, vol. 32, no. 1, pp. 38-52, Jul. 2018.