

AN INVESTIGATION OF PHOTOSYNTHETICALLY ACTIVE RADIATION AT PHRANAKHON RATJABHAT UNIVERSITY, THAILAND

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Abstract

In this work, Photosynthetically active radiation (PAR) was measured at Phranakhon Rajabhat University (13.88°N 100.59°E), Bangkok Thailand. A one year period (2017) of the measurement data was analyzed. The diurnal and seasonal variation of photosynthetically active radiation were investigated. The diurnal pattern shows the maximum values of PAR at local noon time with the highest peak value in March. For the seasonal variation, the monthly average of PAR shows the higher values during the summer and the lower values during the winter. The PAR values ranged from 26.73 mol/m² in January to the highest of 37.02 mol/m² in April and the annual mean value is 31.34 mol/m². Based on measurement data, the model for estimating photosynthetically active radiation from broadband solar radiation was also proposed.

Keywords: Photosynthetically active radiation, measurement, Phranakhon Rajabhat University

Introduction

Photosynthetically active radiation (PAR) is part of solar radiation spectrum in the wavelength band of 400-700 nm. This radiation is absorbed by plants and providing energy for photosynthetic process (McCree, 1972). Thus, PAR is important in plant growth, biomass production and CO₂ exchange between plants and atmosphere. The amount of

PAR incident on the earth's surface is a fundamental input parameter required by most ecosystem models (Sasai *et al.*, 2005; Olofsson *et al.*, 2007). In general, the amount of PAR is measured in terms of photosynthetic photon flux density, (PPFD), in $\mu\text{mol m}^{-2}\text{s}^{-1}$ unit (1 $\mu\text{mol} = 6.022 \times 10^{17}$ photons). This paper presents the analysis of photosynthetically

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active radiation measurements at Phranakhon Rajabhat University, Bangkok, Thailand. The diurnal and seasonal variations of PAR were analyzed. Additionally, a model for estimating photosynthetically active radiation from broadband solar radiation was also proposed.

Materials and Methods

Measurement And Data Analysis

The photosynthetically active radiation and solar radiation measuring equipment was installed on the rooftop of Faculty of Science and Technology building, Phranakhon Rajabhat University, Bangkok, Thailand. This site is at latitude 13.88°N and longitude 100.59°E. An EKO quantum sensor (model ML-020P) was used to measure PAR values. The sensor is silicon photodiode which can filter only radiation in the wavelength interval 400-700 nm. To measure solar radiation, a Kipp & Zonen pyranometer (model CM11) was used. The instruments were connected to a Yokogawa data logger (model FX1012). The output signals in voltage were recorded every second in the datalogger.



Figure 1. The quantum sensor and pyranometer at Phranakhon Rajabhat University, Bangkok, Thailand

The voltage data was converted to PAR irradiance, in $\mu\text{mol m}^{-2}\text{s}^{-1}$, by using the sensitivity of the quantum sensor. Then the value of PAR irradiance was averaged over an hour to obtain hourly PAR value in $\mu\text{mol/m}^2\text{s}$. This hourly PAR data was integrated over a day to obtain daily PAR value in mol/m^2 . In

this work, a one-year period (2017) of PAR data from this measurement was analyzed and the results are presented in the next section.

Results and Discussion

Diurnal Variation of PAR

In order to investigate diurnal variation of PAR, the monthly average hourly PAR value from 6 A.M. to 6 P.M. was calculated. The variation of monthly average hourly PAR irradiance and solar irradiance of each month throughout the year is shown in Figure 2. The diurnal variation of PAR in each month shows that, the PAR value increases from the morning to reach the peak around noon time and then gradually decreases to a minimum in the evening. This variation is mainly influenced from the optical air mass which corresponding to the atmospheric path length, that is the lowest at local noon time. The maximum peak

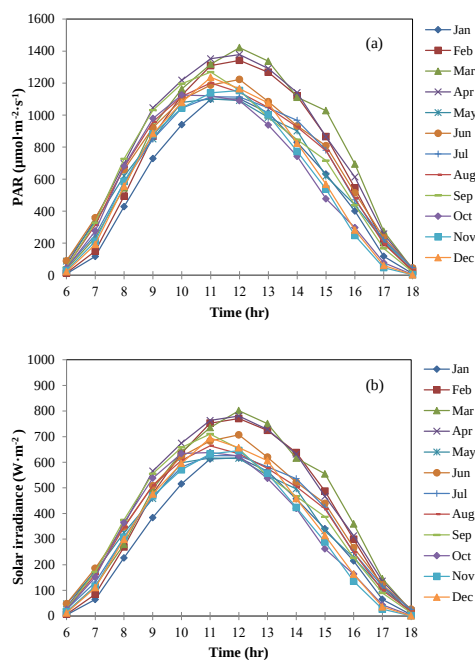


Figure 2. Diurnal variation of the monthly mean hourly (a) PAR irradiance ($\mu\text{mol m}^{-2}\text{s}^{-1}$), (b) solar irradiance (Wm^{-2})

of hourly PAR is $1412.3 \mu\text{mol m}^{-2}\text{s}^{-1}$ in March and the minimum peak is about $1,100 \mu\text{mol m}^{-2}\text{s}^{-1}$ occurs in January and May.

Seasonal variation of PAR

To study the seasonal variation of PAR, the monthly average daily of PAR were calculated. Figure 3. shows the variation of PAR and solar radiation throughout the year which exhibits similar variability. The high value of monthly mean PAR occurred in the summer and the low value of PAR occurred in the winter.

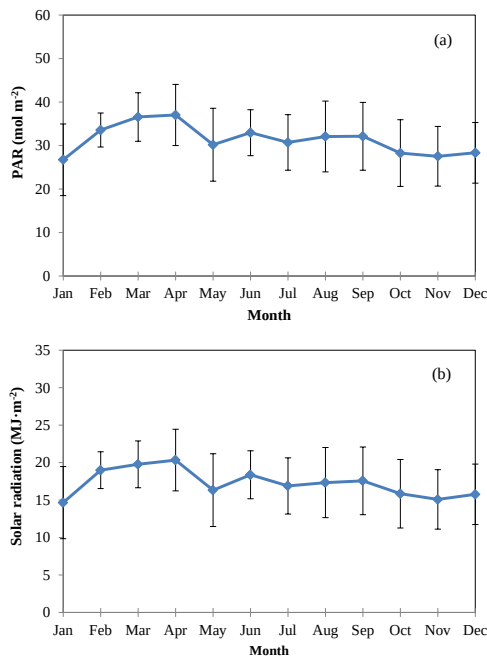


Figure 3. Variation of monthly mean (a) PAR (mol m^{-2}), (b) solar radiation (MJ m^{-2})

The PAR radiation increases from the minimum value of 26.73 mol m^{-2} in January to the maximum value of 37.02 mol m^{-2} in April. This is due to the sun path that moves northward to the celestial equator during this period, resulting in an increase of extraterrestrial PAR. Additionally, January and February are dominated by the northeast monsoon, causing the clear skies. The effect of the northeast monsoon and the sun path caused

the increasing of PAR radiation in this period. March and April are the calm period, the sun at noon time is nearly at the overhead position and the skies are relatively clear which caused the highest PAR value in this period.

Then the PAR value decreases in May and slightly variation to September. The decrease of PAR in this period is mainly due to the southwest monsoon which causing cloudy skies and rainfall. In October to December, the sun path moves southward which results in a decreasing in PAR value. The annual mean value of PAR radiation at this site is 31.34 mol m^{-2} .

Model for Estimating PAR

Since PAR is part of the solar spectrum, the PAR can be estimated from solar radiation data. Many researchers have proposed the ratio of PAR to broadband solar radiation as a constant value or as a function of meteorological parameters (Alados *et al.*, 1996; Jacovides *et al.*, 2004; Li *et al.*, 2010).

To formulate the model, the hourly PAR and solar radiation data was separated into two groups, one for the model formulation and the other for model validation. The data in odd days ($N = 1,654$) was used to formulate the model and the even days data ($N = 1,585$) was used to validate the model. In this work, we express the ratio of PAR to broadband solar radiation as function of the solar zenith angle and the clearness index (ratio of solar radiation to extraterrestrial radiation). The model can be expressed as follows,

$$\frac{\text{PAR}}{R_s} = 2.2169 - 0.1310\cos(Z_s) - 0.9522k_t - 0.7037k_t^2 \quad (1)$$

$$R = 0.75$$

where PAR is hourly photosynthetically active radiation ($\mu\text{mol m}^{-2}\text{s}^{-1}$), R_s is broadband solar radiation (Wm^{-2}), Z_s is solar zenith angle, k_t is hourly clearness index.

To verify the model performance, the model was used to calculate hourly PAR value and the result was compared to the measurement dataset. The result is shown in Figure 4. It was found that the PAR values calculated from the model and the PAR measurements are in good

agreement. The root mean square difference (RMSD) and mean bias difference (MBD) are 0.16% and 3.08% respectively.

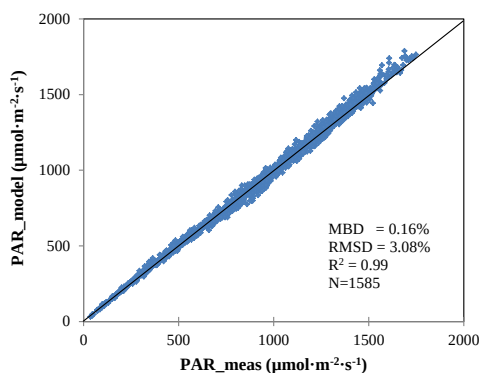


Figure 3. Variation of monthly mean (a) PAR (mol m^{-2}), (b) solar radiation (MJ m^{-2})

Conclusions

Photosynthetically active radiation measured at Phranakhon Rajabhat University, Bangkok, Thailand has been analyzed. The diurnal variation pattern of PAR irradiance shows a normal curve with the peak around the noon time. For the seasonal characteristic, the maximum value of monthly mean PAR is 37.02 mol m^{-2} in April and the minimum value is 26.73 mol m^{-2} in January. The variation of PAR throughout the year was influenced by the variation of sun path and the local monsoons. Finally, a model for estimating PAR from solar radiation has been proposed. The performance of the model was test against measurement data and the result show that, the PAR value calculated from the model agrees with PAR value from the measurement with RMSD is 3.08%.

Acknowledgements

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