The Monsoon Effect on Rainfall and Solar Radiation in Kota Kinabalu

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ABSTRACT Kota Kinabalu is located near the equator with a typically tropical climate, abundant rainfall, high and uniform temperatures, plentiful sunlight and high humidity that comes almost all year. The main economic activities in Kota Kinabalu such as agriculture, fishery, and tourism are highly impacted by the monsoon climate. This study analyzed the monthly time-variability of rainfall and solar radiation in Kota Kinabalu and monsoon temporal from October 2013 to September 2014. The daily average rainfall data were collected from Kota Kinabalu Meteorological Department, while, the solar radiation data with a ten minutes interval were obtained using LI-200 pyronometer. Subsequently, the maximum and minimum monthly average of solar radiation and cumulative rainfall were obtained. The paper examines the observed fluctuation of these variables and attempts to explain their possible relationship. The findings indicate that the period when the southwest monsoon season brings greater rainfall has lesser solar radiation. However, the level of solar radiation does not have an inverse relationship with rainfall amount. This could be due to the variation in air mass, short-term high-intensity rainfall or diurnal variation of rainfall. The city also received higher amount of rainfall in inter-monsoon period in October 2013 than that in the inter-monsoon in April 2014. This phenomenon happened due to the tail effect of typhoons that happen in Philippines. Sudden increases in wind speed up to average 33 km/h also happened during this inter-monsoon period.

KEYWORDS: Monsoon Season; Solar radiation; Rainfall; Variability; Kota Kinabalu

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INTRODUCTION

Kota Kinabalu is the capital city of the state of Sabah, situated in East Malaysia with the latitude and longitude of 6.0367°N, 116.1186°E. It is also known as the coastal capital of the western region of the state. Due to its geographical location, the climate in Kota Kinabalu is classified as equatorial climate with high humidity, a considerable amount of sun, abundant rainfall, and temperatures that are relatively high and extremely invariable throughout the year (Djamila *et al*., 2011). Apart from that, the weather in Kota Kinabalu is also influenced by the northeast monsoons which occurs between November and March, the southwest monsoon from May to September and two inter-monsoons, which usually happen in April and October (Mojiol, 2006).

The monsoon season is a period when higher than normal amount of rain is expected over the western coastal region in Sabah (Ho *et al*., 2013). A good understanding of rainfall variability during the period of monsoon seasons is essential for long-term hydrological and climatological studies and applications, as an input for models of crop growth, design of urban drainage systems, land management systems, and fishery resources (Ho *et al*., 2013), as well as other environmental related activities (Suhaila & Jemain, 2009). Heavy rain falls could also cause floods and landslides that may result in damage to infrastructure, contamination of water supplies and harvest losses. Of course, the shortage of rainfall could also lead to scarcity of water and have an adverse impact on

agricultural yield, in such a way it could bring problems to the economic activities (Alam *et al.*, 2011).

Kota Kinabalu city receives ample amount of solar radiation throughout the year as it is located within the solar belt (40°S to 40°N). The solar radiation is a critical component for climatology, hydrology architecture (Yang & Koike, 2005), crop development and yield prediction, and design of solar energy-based projects (Ahmad & Tiwari, 2011). A study by Sukarno et al., (2013) found the abundant solar irradiation in Kota Kinabalu indicate a great potential for solar energy development. Most agricultural and environmental studies require sets of complete weather data including solar radiations (Semenov & Porter, 1995). Solar radiation data are often required to run a crop development and growth simulation model (Campillo *et al.,* 2012). Adequate solar radiation could help with to increase growth and crop production. In contrast, overexposure to sunlight affect crop productivity and cause drought due to higher temperatures (Simontacchi *et al.,* 2015) Therefore, there is a need for an extensive investigation on the trend of solar radiation and rainfall in the urban region. Most studies on the trend and variability of rainfall during the monsoon seasons were mostly conducted in peninsular Malaysia (Wong *et al.,* 2009; Suhaila & Jemain, 2012). Some of these works have examined trends (Mayowa et al., 2015), the temporal and spatial variability of the rain intensity (Varikoden *et al.,* 2010), and the relationship of inter-annual variability of monsoons with other systems, such as ENSO (Cheang, 1993). Since limited studies have been done in east Malaysia, this study analyzes time-variability in rainfall and solar radiation in Kota Kinabalu during the monsoon seasons.

METHODOLOGY

In this study, data of global solar radiation and rainfall were obtained for a period of one complete year from October 2013 to September 2014. A time series of daily rainfall (mm) were acquired from Kota Kinabalu Meteorological Department recorded at the Kota Kinabalu airport station which is located at 5° 57' N / 116° 03' E. The global solar radiation were measured at the site of Universiti Malaysia Sabah (6.0367°N, 116.1186°E), which is 12 km away from Kota Kinabalu city (5.9714°N, 116.0953°E). The method and devices used to obtain solar radiation were same to that in Sukarno et al (2013). The measurement was taken every 10 minutes from 6am to 6 pm daily. The average and maximum hourly values were calculated from the raw data obtained for every 10 minutes. Daily and monthly statistics for this study were also made for the solar radiation data from the hourly data set. The results are analyzed and discussed in the following parts.

RESULT, ANALYSIS AND DISCUSSION

As has been previously mentioned, the City of Kota Kinabalu experiences two distinct monsoon seasons throughout the year: the Northwest Monsoon and the Southeast Monsoon separated by the shorter inter-monsoonal periods. The Northeast Monsoon season (November to March) is characterized by north-easterly winds with speeds that can be reaching as high as 60 km/h. Whereas, the prevailing winds blow predominately from the southwest at the speed below 30 km/h during southwest monsoon (May to September). During the inter monsoon season (April and October), the winds over the city are generally gentle and variable, in the range of 20 km/h to 30km/h (MMD, 2012).

Rainfall

Kota Kinabalu city has plentiful rainfall. Based on the data collected, it rained an average of 177 days (a day is considered to have "rained" if the total rainfall for that day is 0.2mm or more.) with

approximate total rainfall of 3104 mm. The monthly average rainfall for each day is shown in Figure 1. It was observed that the monthly average rainfall throughout the study is about 8.43 mm. The highest mean monthly rainfall was in December 2013 with 15.12 mm, followed by October 2013 with 15.06 mm. From the result, it also shows that Kota Kinabalu received relatively high monthly average rainfall amount (<10 mm) in August (13.91 mm) and January 2014 (11.94 mm). The lowest amount of rainfall was in April 2014 with an average of 1.69 mm, whereas March 2014 set a record for the second driest month with a monthly average rainfall amount of 1.85 mm.

Solar radiation

The monthly average daily solar radiation in Kota Kinabalu is shown in Figure 2. The city receives the highest intensity of solar radiation in April 2014 (407.89 W/m²), followed by March 2014 with 404.18 W/m² of average solar radiation. The lowest intensity of solar radiation was recorded in January 2014 (278.52 W/m²). In 2014, the monthly average amount of solar radiation being received remains almost the same during southwest monsoon season with 326.82, 322.26, 313.64, 321.00 W/m2 and 347.41 respectively. Overall, the city received a total monthly average solar radiation of 4053.77 W/m2 and monthly average solar radiation of 337.81 W/m2 for the study period.

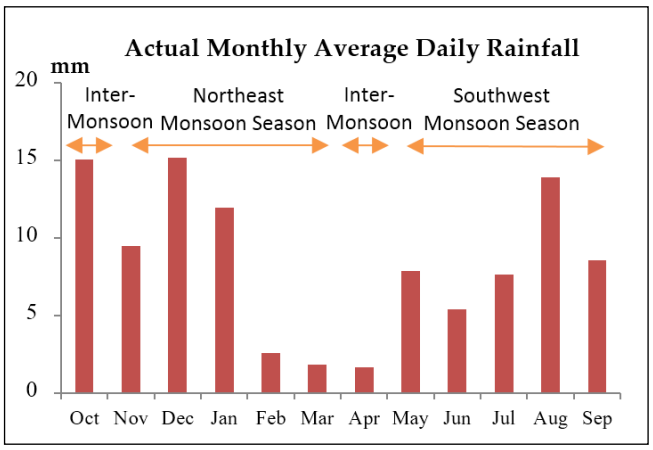

Figure 1. Actual monthly Average Daily rainfall in October 2013 - September 2014

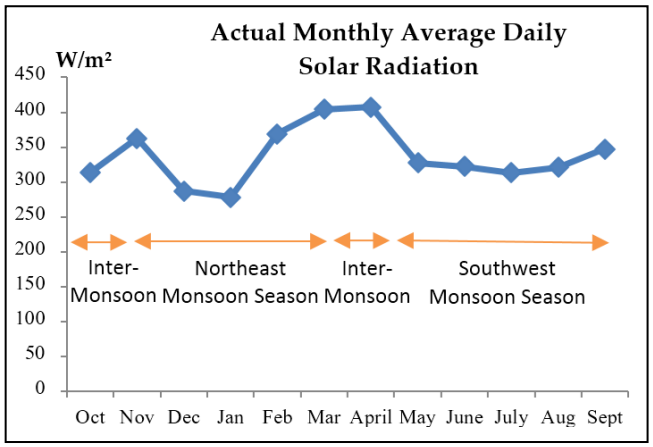

Figure 2. Actual Monthly Average daily solar radiation in October 2013 - September 2014

Since the measurement scales for solar radiation (Figure 1) and rainfall (Figure 2) are different, the normalized monthly average solar radiation and monthly average rainfall are computed for a viable comparison. The result of this normalization is illustrated in Figures 3. The graph shows that the monsoon season that brings greater rainfall also records lower reading of solar radiation and vice versa. The amount of rainfall during the southwest monsoon season (1331 mm) is greater than the amount of northeast monsoon season rainfall (1255 mm). The reading for solar radiation during southwest monsoon season was 1631 W/m², compared to 1702 W/m² in the northeast monsoon season. The findings could be explained with the study by (Diaz, 2017) who suggested that the cloudy condition during the rainy season would obstruct the solar irradiance in the atmosphere enormously, thus reducing the exposure at the surface of Earth.

It is also worth to note that February to April were the months with the least rainfall but these are of course the months with greatest amount of solar radiation. However, some solar radiation variation was not always in opposite path with rainfall variation trend; high rainfall may or may not result in low potential of solar radiation and vice versa. For instances, the maximum average rainfall occurred in December (15.13 mm) but it has the second lowest of solar radiation received with 287.27 W/m² in the same month and the minimum solar radiation was obtained in January (278.52 W/m²), which has the second highest average rainfall reported. Besides that, the solar radiation received had

remained almost constant, but the amount of rainfall received was inconsistent and variable during the southwest monsoon season occurring from May to September These excursions might be because of higher air mass (Riordan *et al.*, 1990), the immediate occurrence of clear sky after a short period of heavy rain or the diurnal variation of rainfall (Mahendran *et al.*, 2013)

Much higher rainfall amounts were reported in inter-monsoon period in October 2013 than that in the inter-monsoon in April 2014. This phenomenon happened due to the tail effect of typhoons that happen in Philippines (Koiting *et al.*, 2015). Sudden increases in wind speed up to average 33 km/h happened during this inter-monsoon period (WBKKO, 2017). As the results, it brought torrential rainfall to the region. However, during the inter-monsoon period in April 2014, the city experienced drier weather conditions with less rainfall. The prevailing northeasterly winds gradually weakened to become light and variable in direction with the average speed of 8km/h (WBKKA, 2017).

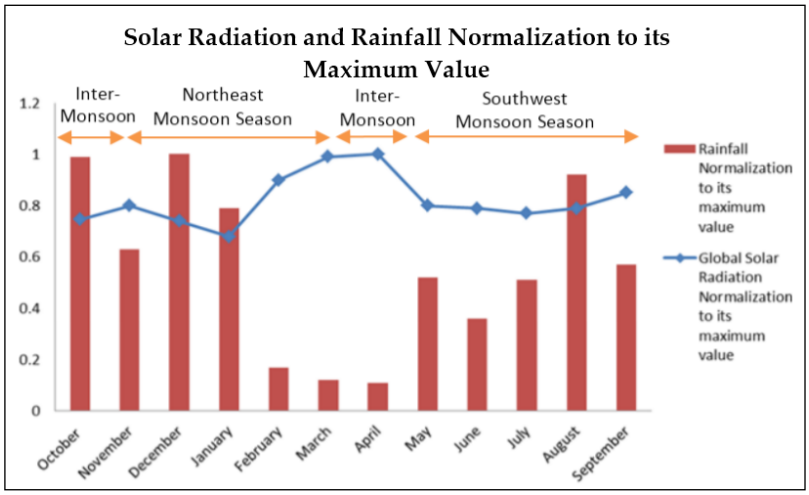

Figure 3. Normalized rainfall and global solar radiation in October 2013 - September 2014

CONCLUSION

This study revealed that the variation of rainfall and solar radiation received in Kota Kinabalu, are mainly influenced by monsoon seasons. The northeast monsoon and southwest monsoon contribute 37% and 40% of the total annual rainfall, respectively. While, solar radiation during the southwest monsoon contributes 40% of the annual solar radiation. The contribution of pre-monsoon (April), post-monsoon (October) and Northeast monsoon to the annual is 10%, 8% and 42%, respectively. The study also showed that monsoon season that brings higher rainfall is expected to have lower solar radiation and vice versa. Months that records high average rainfall nonetheless may not reduce the probability of sunny days.

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