International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-7 Issue-5, February 2018

Climate Change Impact on Water Resources in Baram Basin Malaysia

Nasser Rostam Afshar, Nurainin Mirhassan

Abstract— Climate change is undeniably has become a worldwide issue for the past few decades for its significant impact on water resources. Continuous growing water demand has pushed the natural water resource to the brink whereby the rivers in Sarawak are not spared. For the case of Baram basin, the long term impact of climate change on that regional scale is unapparent. Therefore, a detail study is needed for future back up plan and mitigation. This paper aims at presenting the findings on the rainfall pattern of Baram basin in conformity to the climate regime. By using Classical Multiplicative time-series modeling, data for the year 2005-2014 forecasted and the trend between hydrological parameters(temperature, evaporation and rainfall) and meteorological Parameters (evaporation, temperature, relative humidity, wind speed and cloud cover) is then discussed. From the historical time series trend of hydrological and meteorological data, it was observed that the rainfall trend has decreased within 10 years' time period (2005-2014) due to the change in climate regime. The forecast has predicted decrease in the rainfall trend throughout the future 30 years (2015-2044) and it gives a direct effect on the water resources in terms of its quantity and quality.

Index Terms—Climate change, Rainfall pattern, Water resources, Forecast, Baram basin

I. INTRODUCTION

The issue of climate change has become a concern among many researchers for its significant impact in altering hydrological cycles. According to [1] - [2], global warming is one of the major characteristics of climate change which is caused mainly by the emission of greenhouse gaseous and land use change. Rainfall is the main variable of Malaysia's climate where its variation is influenced by monsoons. Dry seasons and typhoons can occasionally take place in between June to September and July to mid-November respectively as in [3]. In 2014, Malaysia has experienced dry conditions with anomalies more than 60% below the average causing drought in certain areas which include Baram [4].

Furthermore, it was reported that Baram is reeling from the effects of El Nino with the Baram river dropping to dangerously low level and becoming precarious to express boats moving between Marudi and Long Lama. However, not much study has been done in depth in Baram basin and for that reason, potential impact of climate change in the region is still unapparent. Therefore, this paper aims at presenting the findings on the rainfall pattern of Baram basin in conformity to the climate change. The change in rainfall pattern is very much associated with meteorological parameters namely temperature, evaporation, relative humidity, cloud cover and wind speed.

II. HYDROLOGICAL AND METEOROLOGICAL PARAMETERS

In order to examine the historical trend in the rainfall and meteorological parameters, Thiessen polygon and time-series were used. The missing rainfall data was first estimated by using normal ratio method and then data adjusted using double mass curve.

A. Total Mean Annual Areal Rainfall Review Stage

A total of nine rainfall stations which are distributed quite evenly and with the most extensive and adequate data for the past 30 years were chosen namely Benawa (station no. 4043059), Lio Matu (station no. 3152011), Long Akah (station no. 3347003), Long Aton (station no. 3243071), Long Jegan (station no. 3541033), Long Lama (station no. 3744009), Long Seridan (station no. 3950020), Marudi (station no. 4143004) and Miri Airport (station no. 4339005).The mean annual areal rainfall in Baram basin for 30 years are plotted in "Fig.1".

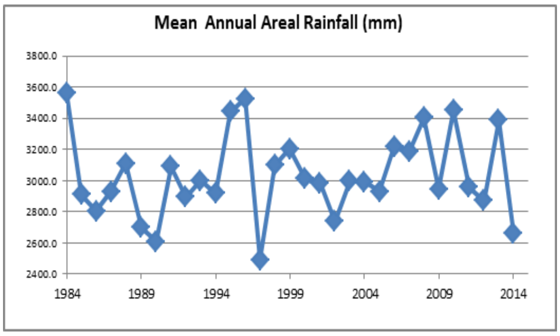

Fig. 1 Mean annual areal rainfall in Baram basin

It can be observed that there is a decrease in the rainfall from year 1984 to 1997, then the rainfall trend increases from year 1997 to 2008 and dropped again from year 2008 to 2014. It can be affirmed that there is more decrement shown in the mean areal rainfall of Baram rather than increment.

Manuscript published on 28 February 2018.
***Correspondence Author(s)**
Associate Prof. Nasser Rostam Afshar, Abbaspour School of Engineering, Shahid Beheshti University, Tehran, Iran, Phone/Mobile No. +989123364880; (e-mail: narafshar@hahoo.com).
Er. Nurainin Mirhassan, Quick Fortune Sdn. Bhd., Kuching, Sarawak, Malaysia, Phone/Mobile No. +60146836823; (e-mail: nurainin_mirhassan@yahoo.com).

B. Time-Series Trend of 6 Parameters

The historical time-series trend of the hydrological and meteorological data for the year 2005-2014 for a decade were plotted by taking Miri Airport as the inventory station. Data is sorted by monsoon as it gives a closer fit between the actual and forecast data. As a whole, it can be clearly indicated that the rainfall, temperature and evaporation trend in Baram has decreased by approximately 2.41mm, 0.08° and 6.28 mm respectively over the past 10 years “Fig.2”to “Fig.4”. Conversely, the relative humidity, cloud cover and wind speed, show an upward trend by 1.91%, 0.007 Oktas and 0.16 m/s for 10 years as in “Fig.5”to “Fig.7”.

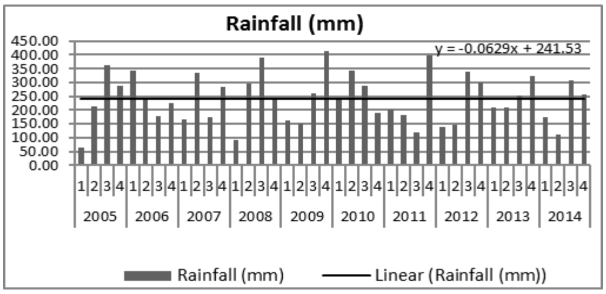

Fig. 2 Rainfall Historical Trend

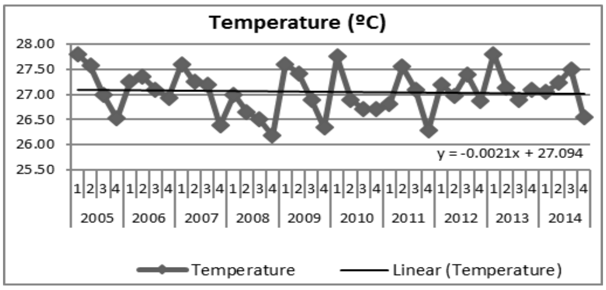

Fig. 3 Temperature Historical Trend

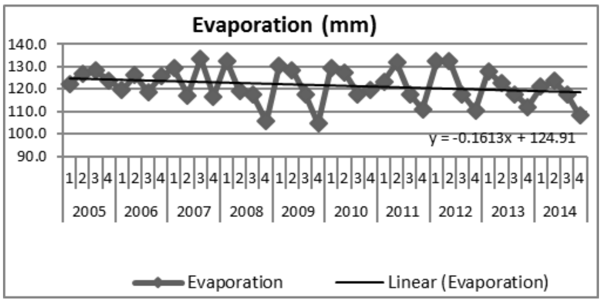

Fig. 4 Evaporation Historical Trend

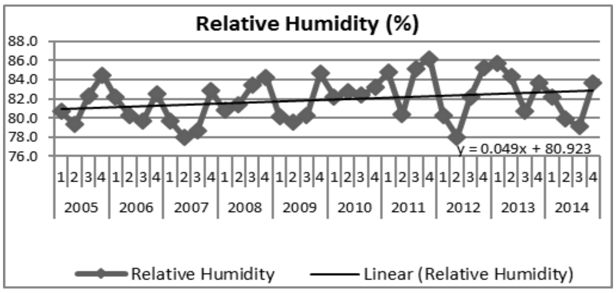

Fig. 5 Relative Humidity Historical Trend

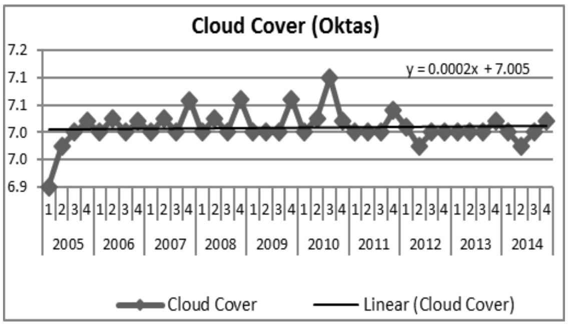

Fig. 6 Cloud Cover Historical Trend

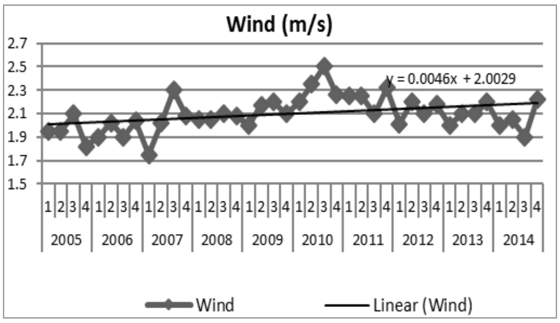

Fig. 7 Wind Speed Historical Trend

C. Relationship between Hydrological and Meteorological Parameters

“Fig.2” to “Fig.4” reveal that the trend for rainfall, temperature and evaporation support the logical theory where evaporation decreases when temperature drops and results in reduction of rainfall. The slight drops in temperature in Baram basin may be due to the huge size of the district, its geography and northern location. Apart from that, a decrease in temperature, reduces the moisture-holding capacity, hence results an increase in relative humidity in Baram basin. Since the moisture-holding capacity of air at a given temperature is limited, air with lesser relative humidity evaporates more water than moist air. Evaporation rate is also very much affected by the cloudiness. A cloudy day gives less sunshine and accordingly less solar radiation results in a lower degree of temperature. Wind flow is one of the factors that affect rainfall distribution patterns. Theoretically, exposed areas such as western Sarawak having a higher wind speed experiences a heavier rainfall compared to the inland areas which are sheltered by mountain ranges. “Fig.2” and “Fig.7” indicate that rainfall and wind speed are inversely proportional. The reason is due to the fact that wind speed increase while pressure decreases and low pressure is often associated with the formation of clouds and rain. According to [5], increase in wind speed increases rainfall loss rate. In addition, a high wind speed removes the saturated air from the evaporating surface and replaces it with dry air which causes more evaporation. The rate of evaporation is exceptionally high whenever there is a combination of high temperature, very low relative humidity and strong winds.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

III. METHODOLOGY

A. *Forecast Trend*

Recent study [6] reveals the ability of Fourier Series to simulate long-term rainfall up to 300 years is viewed as an important finding in the study of rainfall forecast. Long-term rainfall forecasting is viewed to be beneficial to the state of Sarawak in its future planning in various sectors such as water supply, flood mitigation, river transportation as well as agriculture [7]. It may be noted that many forecasting techniques have been developed in recent years. Each has its special use, and care must be taken to select the correct technique for a particular application. The selection of a method depends on many factors specially availability of historical data, the degree of accuracy desirable, the time period to be forecasted, and the time available for making the analysis. Hence, Classical Multiplicative Time-Series Model has been used to forecast the historical data in order to identify the changes in climate in terms of precipitation, temperature, evaporation and solar radiation.

In order to use a historical time series which should be fairly stable and has no significant trend, seasonal, or irregular effects, it is necessary to use smoothing methods to average out the irregular components. For this study, moving average technique which is extremely useful for assessing long-term trends is used. These series then forecasted using Classical Multiplicative Time-Series Model as in (1) in order to examine the impact of climate change on water resources within Kuching area. The data collected over a decade from 2005-2014 for the purposes of analysis.

$$Y_t = S_t \times I_t \times T_t \qquad (1)$$

Where,

Yt is the dependent variable

Tt is the trend component

St is the seasonal component

It is the irregular component

B. *Data Sort Out*

Data arranged by monsoon is more convenient for this study since the gap between the forecast data and the actual data is much closer compare to the data arranged by month. Monsoon is extensive seasonal change of wind direction. Based on current climate, Malaysia experience four monsoons season i.e. southwest monsoon, northeast monsoon, and two shorter periods of inter-monsoon season.

C. *Remove Seasonality and Irregularity*

As trends tend to be obscured by the random errors, some smoothing method is needed. The idea using moving averages for smoothing is that observations which are nearby in time are also likely to be close in value. The average eliminates some of randomness in the data, leaving a smooth trend component.

D. *Extract Seasonal and Irregular Component*

E. *Extract Seasonality*

`In order to quantify the seasonal component and eliminate the irregularity for each season, each irregular component combined for each quarter is average as shown in "Tab.1".

Table 1 Seasonality Component

t	Year	Monsoon	Rainfall (mm)	MA(4)	CMA(4)	S_t, I_t	S_t
1	2005	1	62.25				0.786
2		2	214.63				0.916
3		3	363.00	231.52	266.43	1.362	1.055
4		4	286.20	301.33	305.24	0.938	1.223
5	2006	1	341.50	309.14	285.83	1.195	0.786
6		2	245.88	262.52	254.84	0.965	0.916
7		3	176.50	247.17	225.08	0.784	1.055
8		4	224.80	202.98	214.23	1.049	1.223
9	2007	1	164.75	225.48	224.92	0.732	0.786
10		2	335.88	224.36	231.54	1.451	0.916
11		3	172.00	238.73	229.67	0.749	1.055
12		4	282.30	220.61	215.72	1.309	1.223

F. *Trend Component*

Trend component is obtained by Simple Linear Regression using depersonalized data as Y-variable and the t value as X-variable (using Tool Pak in Microsoft Excel).

IV. OVERVIEW OF THE RESULT AND DISCUSSION

The forecast data or prediction value is obtained by using the Classical Multiplicative Time-Series Model, where it is the product of trend, seasonality and irregularity. Forecasted trend of hydrological and Meteorological Parameters for 30 years are as shown in "Fig.8" to "Fig.13". Referring to the forecasted data, "Fig.8" and "Fig.9", there will be a decrease in the rainfall pattern by 13.31 mm and temperature in Baram will increase very slightly by 0.003°C. The forecast of these 2 parameters supports the simulation made by [8]. Conversely, the evaporation drops around 3.741 mm for the 30 years as in "Fig.10". "Fig.11" to "Fig.13", indicate Positive trend for relative humidity, cloud cover and wind speed parameters, where there is an increment by 1.22%, 0.006 Oktas and 0.12 m/s respectively.

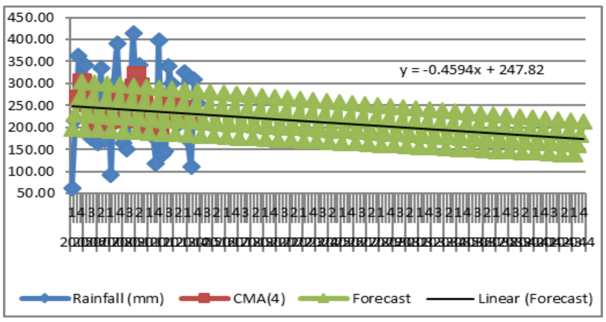

Fig.8 Rainfall Forecast

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

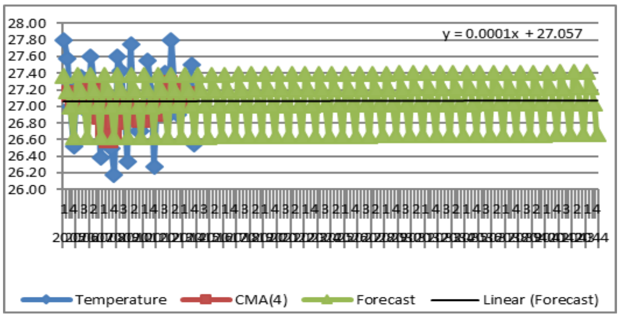

Fig.9 Temperature Forecast

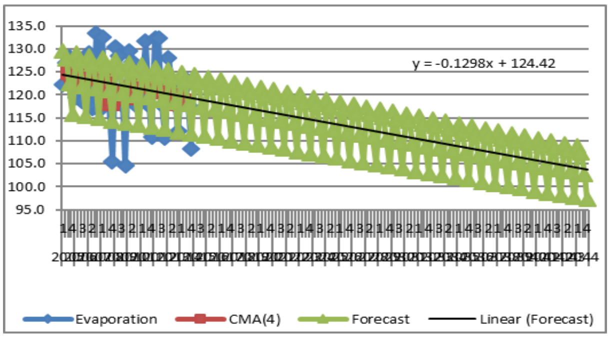

Fig.10 Evaporation Forecast

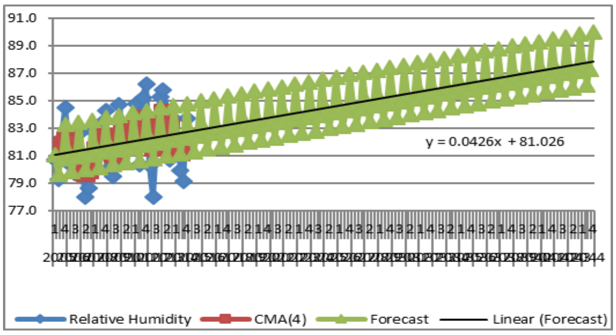

Fig.11 Relative Humidity Forecast

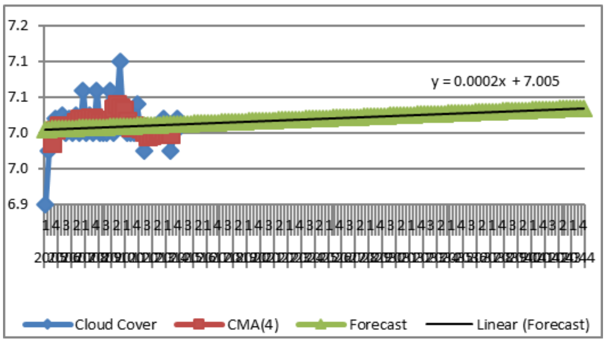

Fig.12 Cloud Cover Forecast

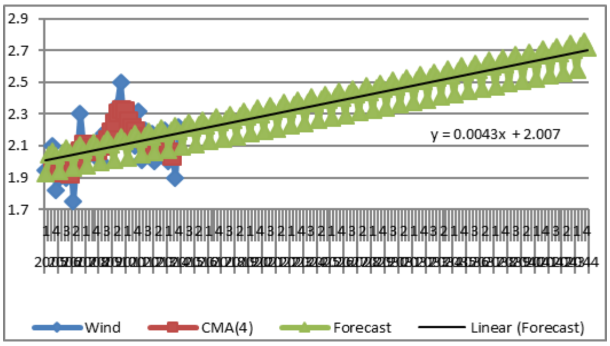

Fig.13 Wind Speed Forecast

A. Potential Impact of Climate Change on Water Resources

The change in rainfall has a direct effect on the fresh water availability and the quality of potable water. Forecasted results obtained for 30 years indicates that the rainfall pattern in Baram or particularly Miri, is predicted to decrease. This phenomenon could lead to drought and land degradation and acute water supply problem would likely to occur. The percentage increase in the population in Sarawak is higher than the percentage increase in water production "Fig.14"as in [9]. Therefore, it is predicted that the water resource in Sarawak including Baram area, may not be sustainable for very much longer since the current source of raw water supplies are almost at their peak safe yield for the catchment from 2030.

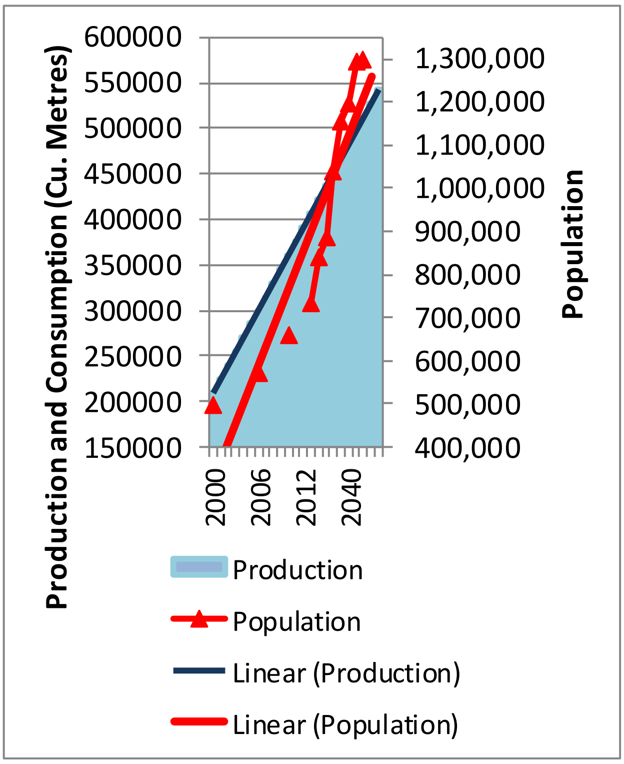

Fig.14 Production v/s population

The forecasted result in Baram shows there will be a future increase in the surface air temperature. Increase in stream temperature increases biological activities and have consequences on nutrients, organic matters as well as biomass within the river environment. Flow variability is the reason for deterioration of water quality as the reduction in water flow increases water pollutant concentration due to lower dilution capacity. It is not impossible for Baram to face such occurrence due to the drops in its rainfall intensity predicted in the future.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

V. CONCLUSION

As a conclusion, the mean annual areal rainfall in Baram for the year 1984-2014 affirmed that there is more decrement in the trend shown rather than more increment. From the historical time series trend of hydrological and meteorological data, it was observed that the rainfall trend has decreased within 10 years from 2005 to 2014 due to the change in climate regime. The forecast of data has predicted decrease in the rainfall trend throughout the future 30 years and it gives a direct effect on the water resources in terms of its quantity and quality. It is believed that the phenomenon is attributable from the change in climate regime. To address this problem, there is an urgent need to understand the relationship between climate change and water resource by doing in depth studies using other approach such as integrated water resource planning. This could help to mitigate climate change variability and uncertainty consequences concerning the issue of shifting water quality, quantity and treatability to develop and implement sustainable water use strategies.

ACKNOWLEDGMENT

The authors wish to express their gratitude to the Department of Civil Engineering UNIMAS and as well as the Department of Irrigation and Drainage (DID), Kota Samarahan, and Meteorological Department Kuching branch for providing the required data.

REFERENCES

1. L Dahlman. (2014, 9). Climate Change, Global Temperature. Retrieved December 12, 2014,). Available: http://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature.
2. United Nations Framework, UNFCCC. (2007,9). *Convention on Climate Change Impacts, Vulnerabilities and Adaptations in Developing Country.* Available: http://unfccc.int/3582.php
3. Hua, T. M. 'Trends of Rainfall in Sarawak from 1999 to 2008". *Proceeding of the International conference on Social Science Research*, ICSSR, 2013, p.261.
4. Malaysian Meteorological Department Mariana Aida Ab. Kadir , (2015, 10), Available: http://www.met.gov.my/
5. Hsu, H. S., Guo, Y. L. *Effect of Wind Speed on the Measurement of Rainfall,* Meiho Institut of Technology, Neipu, Pingtung Hsien: 2005, pp.81-86.
6. Rostam Afshar, N. H. Fahmi. H. (2012, . Rainfall Forecasting Using Fourier Series. *Journal of Civil Engineering & Architecture.* 6(9), 1258-1262.
7. C.B. Beatrice. Nasser R. A. (2014, 11). Application of Mathematical Modelling in RainfallForecast A Case Study in Sungai Sarawak Basin. *International Journal of Research in Engineering and Technology*. 3 (11), 316-319.
8. Intergovenmental Panel on Climate Change. (2008,6). *Technical Paper on Climate Change and Water*, IPCC-XXVIII/Doc.13.
9. N. Rostam Afshar, D.N. Suhaimi "Climate change impact on water resources availability in Kuching, Sarawak". *International UNIMAS STEM Engineering Conference, "Gearing Towards a Greener Future", Kuching, Sarawak.*. 2017.

Nasser, Rostam Afshar, Associate Professor Dr. Nasser is specialized in Hydraulic Structures. He has in his credit teaching, research, industrial, and managerial within the government experiences and private sectors more than thirty years in the field of Hydraulic structures, Hydrology, flood mitigation, Water Resources Planning and Management and Value Engineering.

Nurainin Mirhassan, Master in Civil Engineering specialized in Water Resource Management and currently working at Quick Fortune Sdn. Bhd., Kuching, Sarawak, Malaysia.