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# RELATING CLIMATE VARIABILITIES ON BASEFLOW INDEX IN WAY SEKAMPUNG RIVER AT KUNYIR STATION

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**ABSTRACT**

*Baseflow is very important for water resource management such as irrigation, hydropower generation as well as low-flow forecasting. Baseflow conditions and streamflow volume can be expressed in variability of Baseflow Index. Climate variability, i.e. seasonality and climate change such as El Nino may influence streamflow processes as well as baseflow. Therefore it is important to examine the effect of seasonality and El Nino on baseflow index. This study purposes to investigate the effect of seasonality, i.e. wet and dry seasons, and the effect of El Nino on baseflow index in Way Sekampung River at Kunyir Station. Observed discharge data recorded from the hydrometry station Kunyir is analysed using Recursive Digital Filter (RDF). The result shows that BFI during dry season is higher than that during wet season and BFI in dry seasons during El Nino years are higher than those during normal years. Thus the effect of climate variabilities such as seasonality and El Nino on baseflow index has proven in this study. However, the operation of Batutegi Dam located upstream of Kunyir Station since 2003 has alters baseflow index pattern which does not show the effect of El Nino on baseflow index during El Nino years.*

**Keywords:** baseflow, baseflow index, dry season, El Nino, river discharge

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# 1. INTRODUCTION

Streamflow generation is important in hydrological process as it influences many aspects with respect to life such as water resource management, aquatic ecosystem preservation, hydropower generation, flood and low-flow forecasting. Streamflow consists of three components [1, 2], i.e. surface runoff generated by water that does not infiltrate into the soil and travels quickly to the stream, interflow consisting of water that infiltrates into the soil and travels laterally downslope through upper soil layers, and groundwater flow that infiltrates and travels through the aquifer. Interflow, can moves either slowly or quickly depending on the soil horizon. For hydrograph separation purpose, streamflow is divided into two parts, stormflow and baseflow. Stormflow consists of surface runoff and the quickflow portion of interflow, while baseflow consists of groundwater flow and the portion of interflow moving slowly through the subsoil.

Baseflow is typically estimated through analysis of streamflow time-series hydrographs by separating streamflow into the stormflow and baseflow [3]. Various techniques exist for hydrograph separation [4, 5] including manual graphical [6], automated filtering [7, 8], and tracer based methods [9, 10]. In this study Recursive Digital Filter (RDF) which belongs to automated filtering is occupied to investigate baseflow separation. Specifically RDF method offers an analysis to calculate baseflow index (BFI) meaning the portion of baseflow from total flow.

Increasing demands on groundwater, changes in land-use, and changes in precipitation patterns due to climate change all are expected to impact baseflow conditions and streamflow volume, which can be expressed in variability of Baseflow Index. In terms of climate variability, seasonality and climate change such as El Nino may influence streamflow processes as well as baseflow [11, 12]. However, there is not many study which investigate the relationship of El Nino on baseflow index.

El Nino Southern Oscillation (ENSO) events are relatively discrete climatic patterns that occur at intervals of 3–7 years. The El Nino phenomenon refers to a warming of the tropical pacific basin in association with a weakening of the trade winds. The El Nino event in 1997–1998 is considered one of the strongest on record, with major climatic impacts felt around the world (Timmermann, 1999) [13]. ENSO indices for the years 1968–2017 were obtained from the NOAA Climate Prediction Centre [14] which indicated that during those years El Nino occurred several times in this region [15].

This study takes place in Way Sekampung basin, which is located in Lampung Province, Indonesia. It is important to understand how El Nino effect on streamflow generation, especially baseflow, in this basin. Baseflow is particularly important in Way Sekampung basin, as the basin utilizes Way Sekampung river intensively for many purposes. Way Sekampung basin has cascade hydraulic structures such as Batutegi dam, Argoguruh Weir, Sekampung dam, Margatiga dam and Jabung weir. Batutegi dam supports Sekampung irrigation system which irrigate potential area of 76,000 Ha and fungtional area of 55,000 Ha [16]. In addition to irrigation, Batutegi dam is utilized for hydropower and fresh water source for surrounding cities, while Sekampung and Margatiga dams are meant for irrigation too. Therefore it is important to prevent water availability in the river throughout the year especially during dry season.

Discharge data used in this study is collected from hydrometry station Kunyir which is located downstream of Batutegi Dam as presented in Figure 1. Batutegi Dam was built from 2000-2003 and started operating since 2003. Therefore it is interesting to learn whether there is a change in Baseflow Index pattern before and after the operation of Batutegi Dam. This study purposes to investigate the effect of seasonality, i.e. wet and dry seasons, and the effect of El Nino on baseflow index in Way Sekampung River at Kunyir station. This study considers those effects on baseflow index both before and after the operation of Batutegi Dam.

## 2. METHODOLOGY

This study takes place in Way Sekampung which geographically located in Lampung Province, Sumatera island, Indonesa. Annual rainfall depths are high with the annual mean exceeding 2000 mm and show substantial seasonal variations. Wet season occurred between November and March/April, and dry season occurred between May/June and September/ October. On inter-annual time scales, the ENSO is believed to be a major factor influencing climate, most particularly rainfall, which can show strong deficits during major El Ninos [17, 18].

Data used in this research is daily discharge data from 1968 to 2017 collected from hydrometry station Kunyir, located at the downstream of Batutegi Dam, in Lampung Province as shown in Figure 1.

Observed discharge data recorded at Kunyir station is analysed using Recursive Digital Filter (RDF). There are several methods included in Recursive Digital Filters used in this study, i.e. BFLOW (Lyne & Holick *algorithm*), *Chapman Algorithm*, EWMA (*Exponentially Weighted Moving Average*), and Nathan & McMahon. The algorithms used to calculate for each method are summarized as shown in Table 1, with $qf_{(i)}$ is *quickflow* at day-*i* ($m^3/s$), $qf_{(i-1)}$ *quickflow* at previous day (*i-1*) ($m^3/s$), $q_{(i)}$ total discharge at day -*i* ($m^3/s$), $q_{(i-1)}$ discharge at previous day ($m^3/s$), q*b* is *baseflow* ($m^3/s$), α and b filtering parameters. For Lynn & Holick, Chapman and Nathan & McMahon methods to calculate baseflow is used this equation: $qb_{(i)} = q_{(i)} - qf_{(i)}$. Some illustration results using the RDF methods applied for baseflow analysis in Way Kunyir for year 1999 are presented in Figure 2.

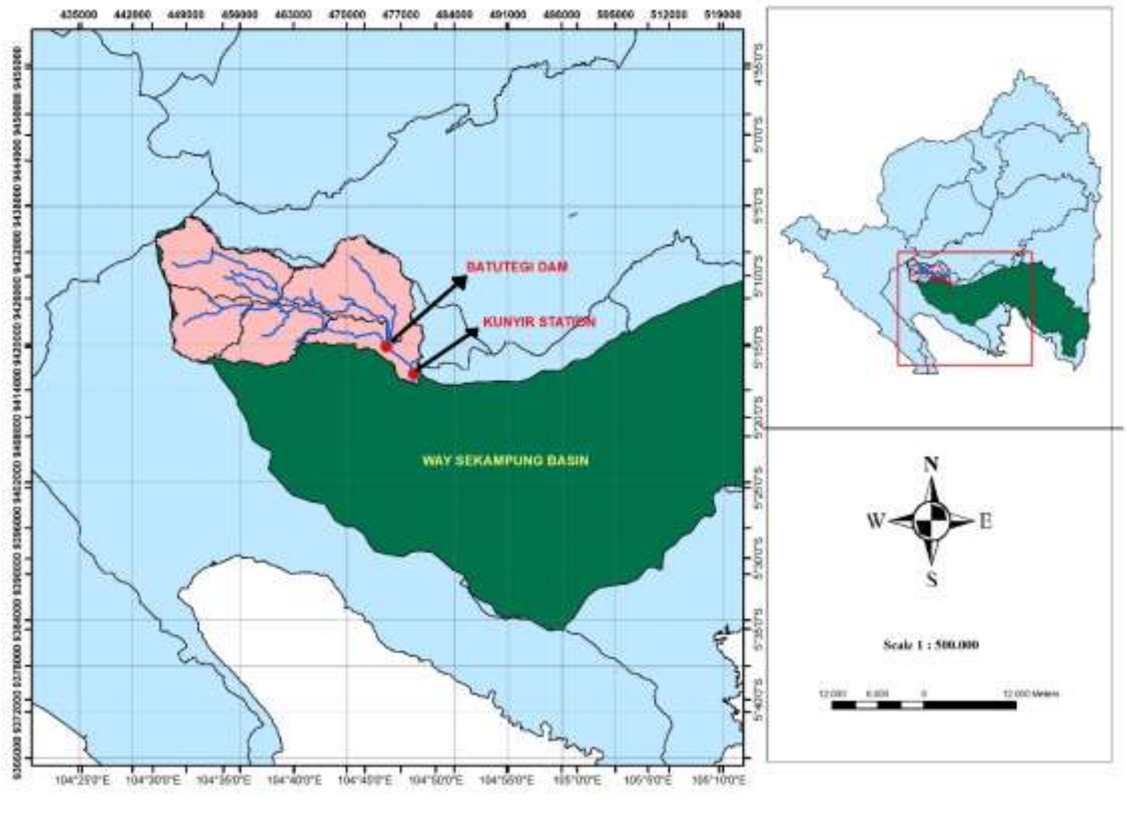


**Figure 1** Study Area

**Table 1**. RDF Methods and the equations

| RDF Methods | Equations |
|---|---|
| Lynn & Holick | $qf_{(i)} = \alpha qf_{(i-1)} + (q_{(i)} - q_{(i-1)})\frac{1+\alpha}{2}$ |
| EWMA | $qb_{(i)} = \alpha q_{(i)} + (1-\alpha) qb_{(i-1)}$ |
| Chapman | $qf_{(i)} = \frac{3\alpha - 1}{3-\alpha}\alpha qf_{(i-1)} + \frac{2}{3-\alpha}\left(q_{(i)} - \alpha q_{(i-1)}\right)$ |
| Nathan & McMahon | $qf_{(i)} = \alpha qf_{(i-1)} + \beta\,(1+\alpha)\left(q_{(i)} - q_{(i-1)}\right)$ |

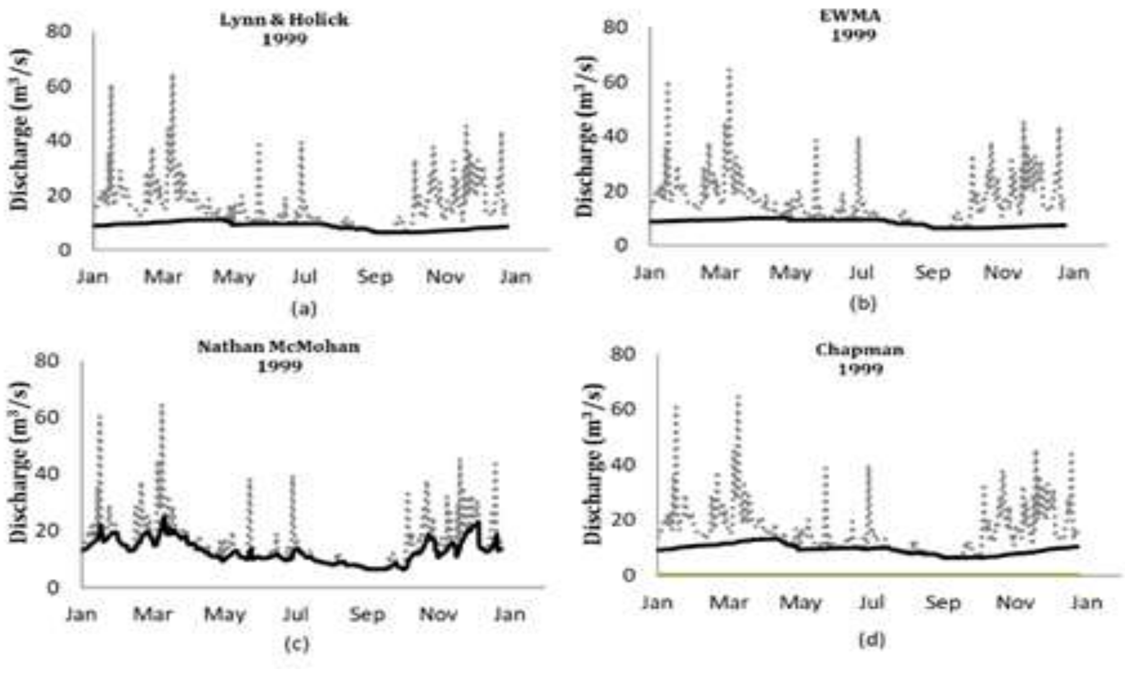


**Figure 2**. Illustration of total discharge and baseflow hydrographs using RDF methods: (a) Lynn & Holick, (b) EWMA, (c) Nathan McMohan, and (d) Chapman.

## 3. RESULTS AND DISCUSSION

Typical discharge hydrograph in Way Sekampung Basin is wet season during November to May and dry season during June to October. Examples of discharge hydrographs in normal years without El Nino phenomena such as those in 1971and 1980 are presented in Figure 3a and b, while that in 1999 is presented in Figure 2. The figures shows time variability of discharge during one year period with high discharges occur during wet seasons, while less discharges during dry seasons flowing in the river as a result of less precipitation fell in the basin.

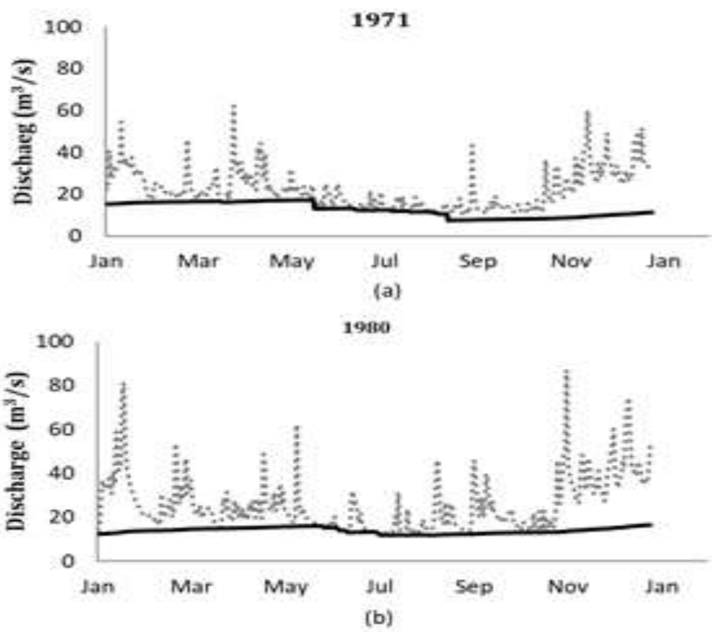


**Figure 3**. Discharge hydrographs for year (a) 1971 and (b) 1980

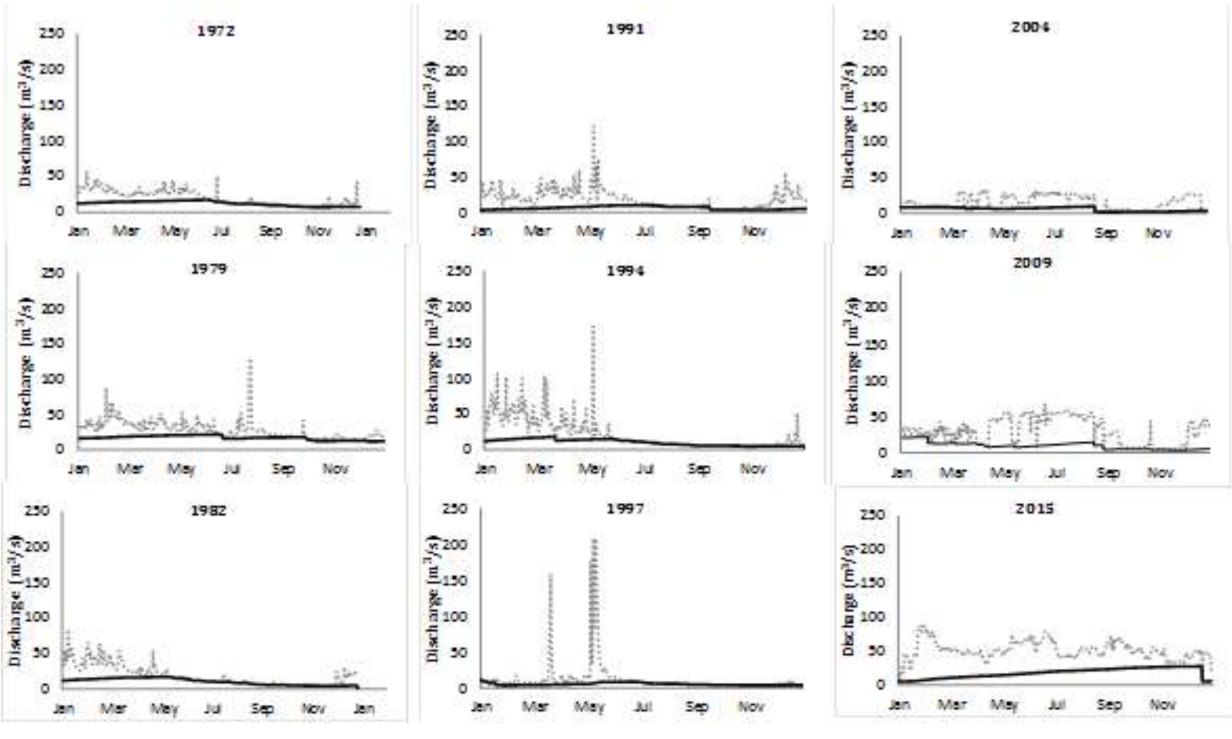


**Figure 4**. Daily discharge hydrographs for years 1972, 1979, 1982, 1991, 1994, 1997, 2005, 2009 and 2015

Discharge hydrographs in the years affected by El Nino phenomena are shown in Figure 4 presenting the hydrographs for year 1972, 1979, 1982, 1991, 1994, 1997, 2004, 2009 and 2015. It is shown that during dry season, drought occur in Way Sekampung basin. Longer dry period is indicated in 1997, when low flow occurred until the end of the year. In addition, it can be observed from the hydrographs of the years 2004, 2009 and 2015 that there is a change in those hydrograph patterns compared to the hydrographs of the precending years. As Station Kunyir is located downstream of Batutegi Dam, the river recieves releasing water from the dam depending on water need either for irrigation, water supply or hydropower. Therefore since the operation of the dam in 2003 the hydrograph at Kunyir station does not fully reflect seasonality.

Lynn and Holick method was used in separating baseflow for those years as it is shown in Figures 3 and 4. Yearly BFI indexes for those years are 0.57, 0.54 and 0.56 for years 1971, 1980 and 1999 respectively. While for El Nino effected years the BFIs are 0.59, 0,59, 0.55, 0.32, 0.46, 0.44, 0.34, 0.33 and 0.37 for the years of 1972, 1979, 1982, 1991, 1994, 1997, 2004, 2009 and 2015 respectively. There is no significant difference in yearly BFI indexes between the years affected by El Nino and those which are not affected. Yearly BFI of year 1968 to 2017 are presented in Figure 5 with minimum, maximum and average yearly BFI indexes are 0.16, 0.69 and 0.44 respectively. It can be noticed that there is a decreased trend in yearly BFI.

An investigation on BFI trends using other RDF methods is presented in Table 2. It is confirmed that all methods show a decreased trend of BFI. The methods of Lynn & Holick, EWMA and Chapman give similar results on the slope, intercept and standard deviation of yearly BFI regression lines. However, Nathan & McMahon method gives large difference to other methods on those variables. As presented in Figure 2, Nathan & McMahon method considers baseflow separation for each individual flood event. Thus this method usually gives a larger baseflow index compared to other methods. Analysis of regression line of yearly BFI using this method show milder slope and smaller standard deviation compared those resulted from other methods (Table 2).

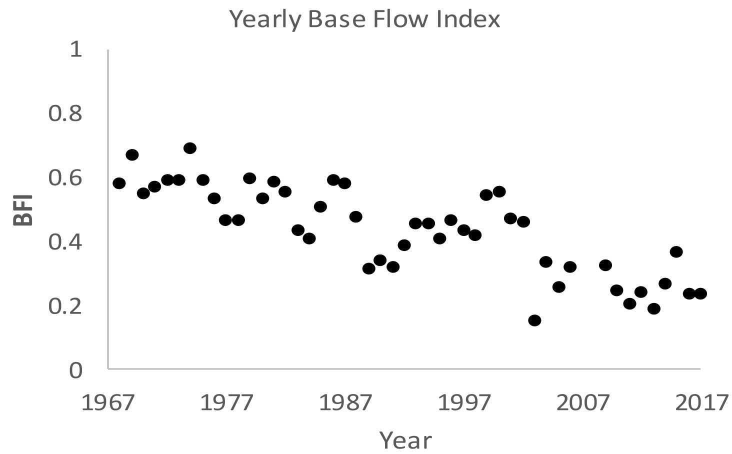


**Figure 5**. Yearly Base Flow Index

**Table 2**. Variables for regression lines representing yearly BFI for several RDF methods

| Methods | Slope (b) | Intercept (a) | Std Dev |
|---|---|---|---|
| Lynn & Holick | -0.0078 | 15.920 | 0.11345 |
| EWMA | -0.0066 | 13.510 | 0.09600 |
| Chapman | -0.0083 | 17.094 | 0.12072 |
| Nathan & McMahon | -0.0027 | 6.070 | 0.03927 |

In contrast, monthly BFI shows more significant difference in representing dry and wet seasons as presented in Figure 6, the graph composed using 50 years discharge data from 1968 -2017. The average of monthly BFI during dry season (June – October) tend to be higher compared to those during wet season (November to May). Average monthly BFI during dry season is in the range of 0.71 to 0.77. Average monthly BFI during wet season, especialy those for the month of December to April, is in the range of 0.4 to 0.48. While for transition months from wet to dry and from dry to wet, average monthly BFIs are 0.58 and 0.53 for May and November respectively. Furthermore, maximum monthly BFIs during dry season are higher compared to those during wet season. Maximum monthly BFIs for November to May range from 0.73 to 0.86 and maximum monthly BFIs for dry season range from 0.96 to 0.99.

Further investigation on the average of monthly BFI was done by using other methods of RDF, i.e. EWMA, Chapman and Nathan & McMahon and the result is presented in Figure 7. It is shown that all methods show similar trend that during dry season, June to October average monthly BFIs are higher compared to those during wet season. The average monthly BFIs for dry season are 0.57-0.67, 0.73-0.8, 0.84-0.88 for EWMA, Chapman and Nathan & McMahon methods, and average monthly BFIs for wet season are 0.35-0.4, 0.49-0.58 and 0.75-0.83 for EWMA, Chapman and Nathan&McMahon methods.

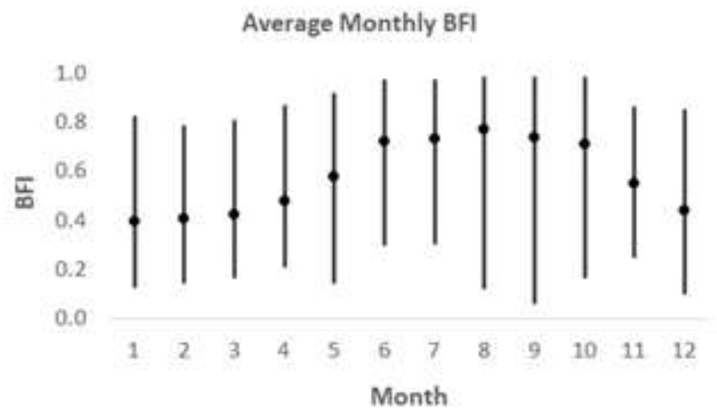


**Figure 6**. Average monthly BFI using Lynn & Hollick method for Hydrometry Station Kunyir (1968 – 2017)

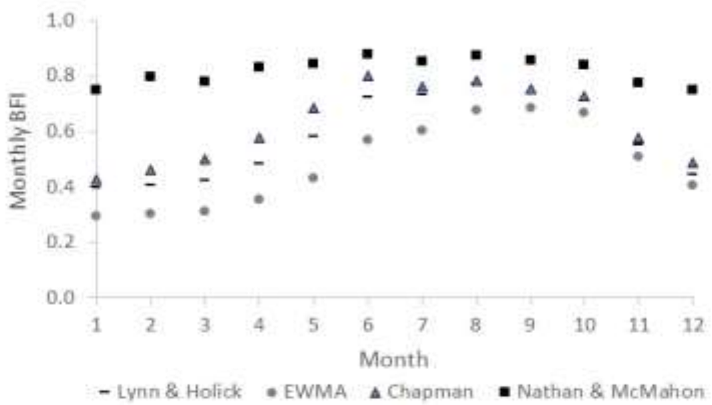


**Figure 7**. Average monthly BFI using several RDF methods

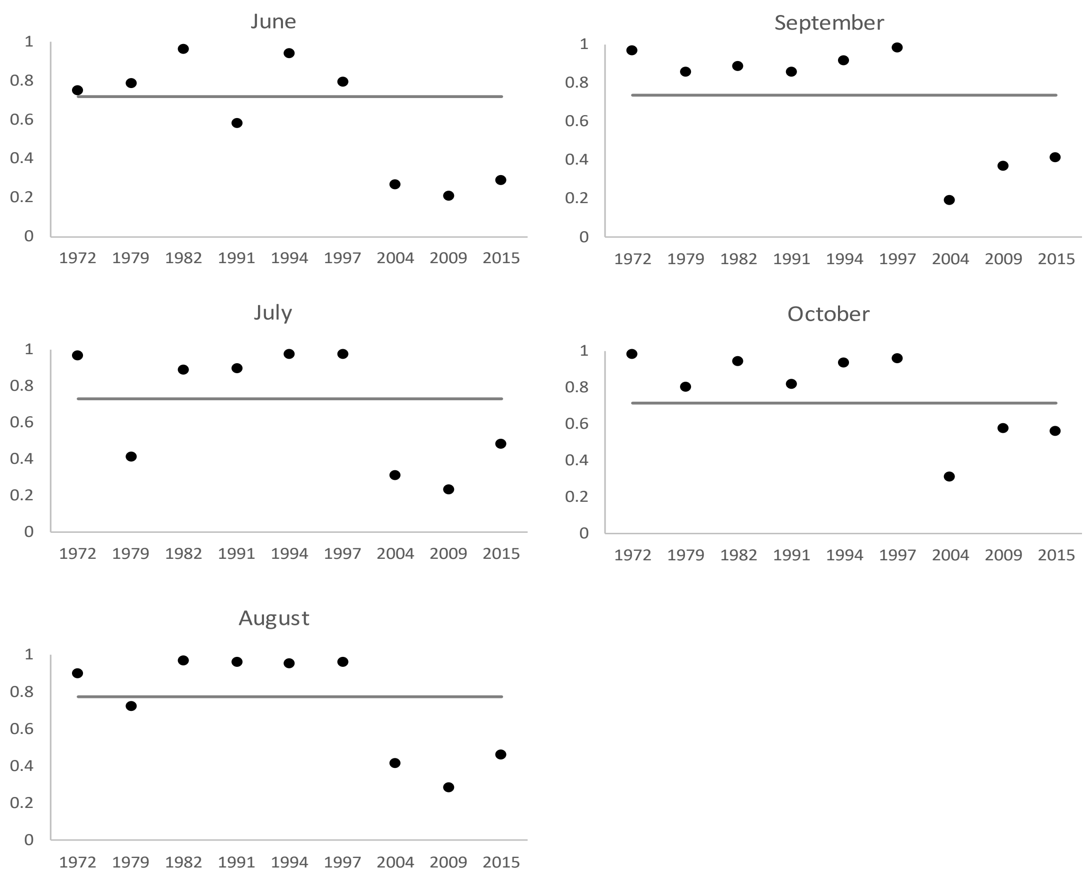


**Figure 8**. BFIs during dry season in El Nino years compared to average monthly BFI

Figure 8 shows baseflow index for the months of June, July, August, September and October in El Nino years compared to the average BFI of the corresponding month. It can be observed that in 1971, 1982, 1994 and 1997 BFI values for each month during dry season are higher than the average BFI values of corresponding months. In 1979 BFI values for June and July fall below the average monthly values and in 1991 BFI value for June is less than corresponding monthly BFI. In general this study shows that El Nino has an effect on baseflow index, which is demonstrated by higher BFI values during dry season than the corresponding average monthly BFIs. The strength of El Nino effect can be detected whether BFI values consistently higher than corresponding monthly BFI values during dry season. On the contrary, BFI values during dry season in 2004, 2009 and 2015 are all below the average BFIs of the corresponding months. This is due to the characteristic of the discharge of Sekampung River at Kunyir Station does not reflect seasonality as the river discharge only represents water release from Batutegi Dam which has been operated since 2003. Therefore the effect of El Nino cannot be noticed in Kunyir station during those years. The effect of El Nino may be noticed in the part of Way Sekampung River far downstream of the Batutegi Dam.

It is obvious that during dry season baseflow is considered to contribute the most to the river flow. Irrigation, hydropower generation and other purposes rely on continuity of river flow throughout the year especially during dry season. Therefore, conservation of the upstream catchment is essential to retain water and release it slowly as baseflow throughout the year.

## 4. CONCLUSION

The effect of climate variabilities is evident in time series discharge in Way Sekampung Basin using Baseflow Index. In the annual cycle, seasonal variabilities such as dry and wet seasons relate to BFI; during dry season BFI values are found to be higher compared to those on wet season. Furthermore, El Nino phenomena which have occurred several times in Way Sekampung basin, has shown its impact on the discharges of Way Sekampung River, where, BFI values on dry season during El Nino years are higher than those in normal years. Another finding from this study yearly baseflow index tend to decrease for all RDF methods. The operation of Batutegi Dam since 2003 has changed baseflow index pattern in Way Sekampung River at Kunyir station. Climate change such as El Nino has no impact on baseflow index during El Nino years. This is due to discharge amount in the river depends on water release from the dam. Nevertheless, the result suggests that water resources management baseflow plays an important role to prevent availability of river discharge throughout the year.

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