TREND ANALYSIS AND IDENTIFYING PRECIPITATION ALTERING OF CLIMATE CHANGE SCENARIOS USING MANN-KENDALL TEST IN THE NAKDONG RIVER BASIN IN KOREA

Ngo Van Quan[1]

Abstract: *Purpose of this study is to investigate for trend identifying of climate change data in Nakdong river basin. In this study, the Mann-Kendall test method was used to detect trends in a time series of climate change data for precipitation data at sixteen stations in region with period 1983-2098 (117 years) under scenarios as A2, B1 and A1B. Results showed the positive trend with 95% confidence interval at three stations, four stations, and four stations under A2, B1, and A1B respectively. Moreover, the results obtained with the Mann-Kendall tests showed agreement in their assessments of monthly, seasonal, and annual precipitation trends. The variability of negative and positive trends at various stations points to the need for more detailed studies on the climate change of this region. In addition, the result of Mann-Kendall test also detected that the downstream of basin under most of scenarios will receive precipitation much more than upstream in Nakdong river basin in the future. These results of study could be useful to provide for managers in water resources planning and management in this region.*

Key words: Climate change, Detection, Identify, Mann-Kendall, Nakdong river.

1. INTRODUCTION

Climate change is significantly negative influencing on agricultural river basins and it is severe challenge for all water resources managers in the world. Accurately predicting precipitation trends can play an important role in a basin's future economic development. Trend analysis of data helps us identify trends at numerous locations within a region is very necessary. Recently, a number of studies which have been conducted have shown evidence of significant changes in hydro-meteorological variables by analysing historical data trends (Qian et al., 2007). The IPCC also confirmed an increasing number of heavy precipitation events over the last 50 years (IPCC, 2007). The analysed the relationships between annual and seasonal mean and extreme trends across Australia and the globe using extreme climate indices estimated using daily temperature and precipitation data for 1957-2005 (Alexander et al., 2007). Study of different time series data have proved that trend is either decreasing or increasing, both in case of temperature and rainfall. The annual relationships of trends between the mean and the extreme of precipitation in Australia are very highly correlated and consistent with other global regions studied. Some studies have addressed similar trend analysis of hydroclimatic variables to that of Korea (Baek et al., 2005). Most past studies, however, have focused on climatic trend analyses in the history data and as short term time series in the basin. The studies have not focused on precipitation trend in future period with long term in the Nakdong river basin.

Nakdong river basin is large region that is facing adverse effects of disaster in almost every year. Therefore, the identifying and analyses to assessing one of climatic variable trend as precipitation is the most important in region. This study fills this research gap with the Mann-Kendall test which is used to obtain objective of study based on considers precipitation data from 117 years (1983 - 2098) at 16 stations. This research is to investigate trends and variations in precipitation over time at the Nakdong basin, and to provide a broad overview of precipitation statistics, and may help managers and agricultural planners.

[1] *Division of Water Resources Engineering, Thuy loi University, Vietnam.*

2. STUDY AREA

The Nakdong River basin is situated in the monsoon region of South Korea (35–37° N, 127–129° E) (Finger 1).

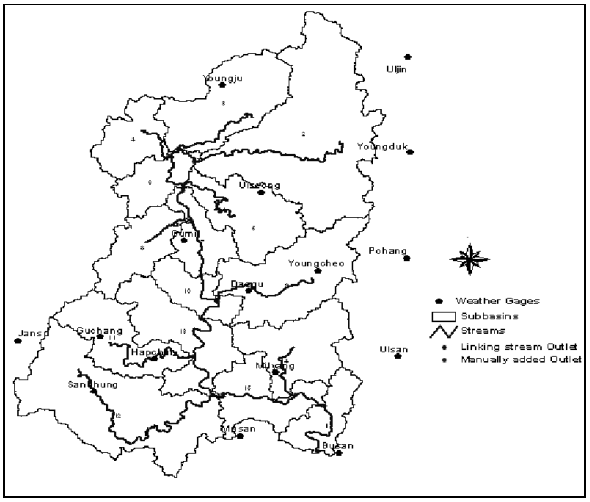


Figure 1. Location of study area

This region is characterized by heavy rainfall in the monsoon season in early summer from June to August. The river drains an area of 23.817 km2 and length of the main stream is over 525 km.

3. METHOD AND DATA

In this study, the precipitation data have been used to analysis of trend at sixteen stations in Nakdong river basin. The Mann-Kendall test method was used to identify a trend in time series. This method is a nonparametric test for detecting trends in a time series of data. The test is widely used for analysing environmental data, and water quality data (Donohue et al., 2001). The Mann-Kendall test is simple but robust and has the advantage of being able to deal with missing values and values below a detection limit (Mann et al., 1945). A new multivariate test for a monotone trend based on Kendall's statistics was proposed (Dietz et al., 1981). The method was further extended in order to analysis multiple monitoring sites and covariates representing natural fluctuations (Libiseller et al., 2002).

The Mann-Kendall test is applicable in cases when the data values *xi* of a time series can be assumed to obey the model

$$X_i = f(t) + \varepsilon_i \qquad (1)$$

Where f(t) is a continuous monotonic increasing or decreasing function of time and the residuals ε_i can be assumed to be from the same distribution with zero mean. It is therefore assumed that the variance of the distribution is constant in time. We want to test the null hypothesis of no trend, Ho, i.e. the observations xi are randomly ordered in time, against the alternative hypothesis, H1, where there is an increasing or decreasing monotonic trend.

The Mann-Kendall test statistic S is calculated using the formula as follow

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \mathrm{sgn}(x_j - x_k) \qquad (2)$$

where xj and xk are the annual values in years j and k (annual values of precipitation), j > k, respectively, n is the length of the data set, and

$$Sgn(x_j - x_k) = \begin{cases} 1 & if\ x_j - x_k > 0 \\ 0 & if\ x_j - x_k = 0 \\ -1 & if\ x_j - x_k < 0 \end{cases} \qquad (3)$$

Firstly, the variance of S is computed by the following equation, which takes into account that ties may be present:

$$Var(S) = \frac{n\left(n-1)(2n+5) - \sum_{p=1}^{q}(t_p - 1)(2t_p + 5)\right)}{18} \qquad (4)$$

Where: q is the number of tied groups and t_p is the number of data values in the p^{th} tied group. S is expected to have N(0,var(S)) distribution with the null hypothesis H_0 that there is no trend displayed by the time series.

Secondly, the values of S and VAR(S) are used to compute the test statistic Z as follows

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{\mathrm{var}(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \dfrac{S+1}{\sqrt{\mathrm{var}(S)}} & if\ S < 0 \end{cases} \qquad (5)$$

where, Z is a standard normal variable and the presence of a statistically significant trend is evaluated using the Z value. The Mann-Kendall test may thereby be stated simply. The null hypothesis H_0 that Z is not statistically

significant or no significant trend is accepted if $-Z_{1-\alpha/2} \le Z \le Z_{1-\alpha/2}$, where $\pm Z_{1-\alpha/2}$ are obtained from the standard normal deviates, α is the significance level for the test. The presence of a statistically significant trend is evaluated using the Z value. A positive (negative) value of Z indicates an upward (downward) trend.

To estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method is used. The Sen's method can be used in cases where the trend can be assumed to be linear. This means that f(t) in equation (1) is equal to

$$f(t) = \theta t + B \qquad (6)$$

where θ is the slope and B is a constant. To get the slope estimate θ in equation (Eq. 6) the first calculate the slopes of all data value pairs

$$\theta_i = \frac{x_j - x_k}{j - k} \qquad (7)$$

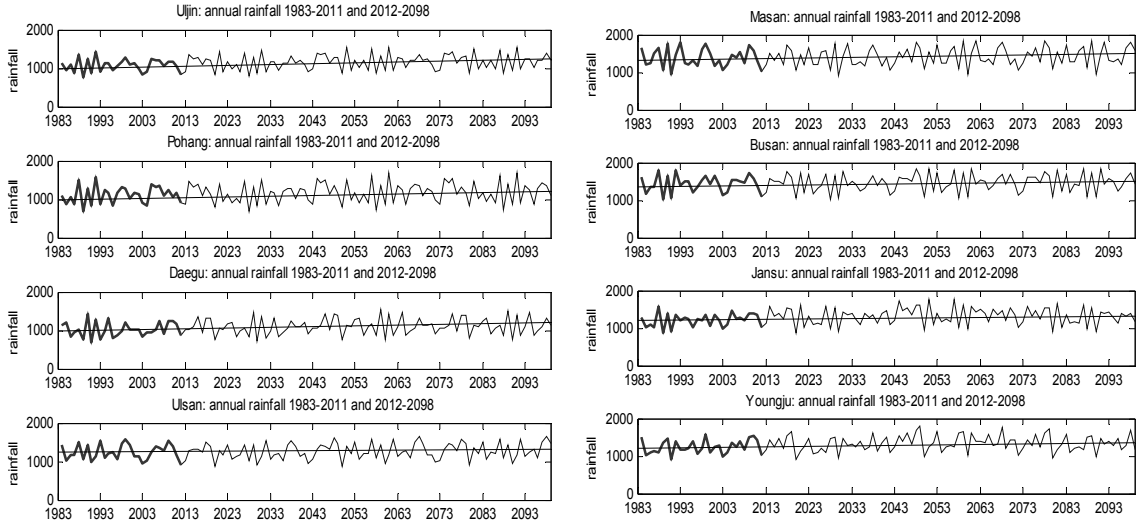
where j>k. If there are n values xj in the time series we get as many as N = n(n-1)/2 slope estimates θi. The Sen's estimator of slope is the median of these N values of θi.

The output file for each test list the correlation coefficient include Kendal test statistic S, the standard normal deviated Z, determined from S and the variance of S, the p-value for significance of the trend, and slope also estimated in this file.

In this study, The climate change data were obtained from GCMs of ECHO-G under A2, B1, and A1B scenarios that were used to assess and to identify of change in the future. These data obtained based on available data for future long tern of 2012-2098. However, in order to advantage in comparison and assessment as well as identification of in change of future periods to relative observed baseline period of 29years (1983-2011), so the future long period was divided into three periods for each period as 29years of 2012-2040, 2041-2069, and 2070-2098. Then, these periods were selected to assess and compare with baseline period (1983-2011). This is basis reason why those periods are used in this study.

4. RESULTS

The figure 2 has shown the trends in the future for 16 stations under A2 scenario, respectively. The results of a Mann-Kendall test was carried out on annual precipitation that during for 30 years in current and the 87 years climate in future at sixteen stations have shown significant positive trend for stations under A2, B1, and A1B. Under A2 scenario**,** the result detected three stations with significant positive trend with a 95% confidence interval. Two of these stations (Uljin, Youngduk) are located in the upstream of the basin, one another of these stations (Masan) detected in downstream of the basin.



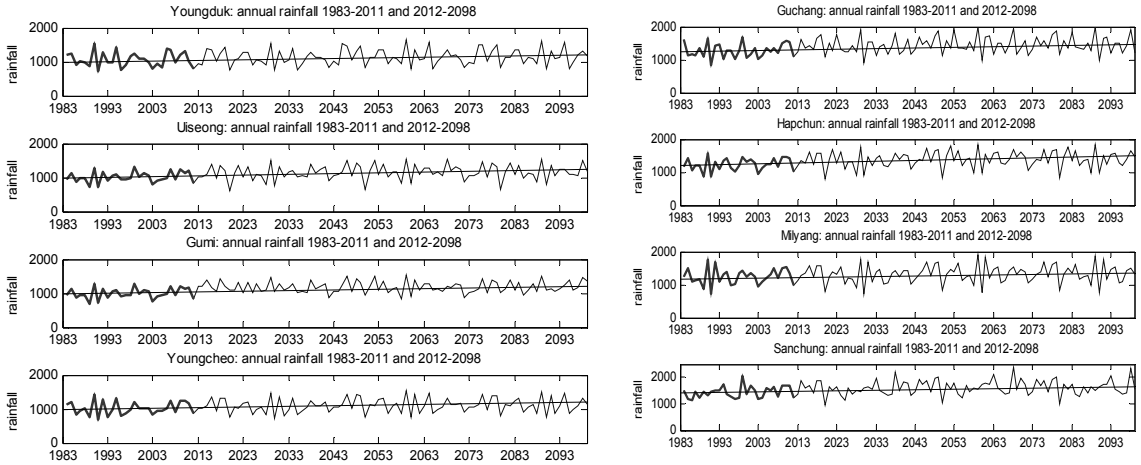


Figure 2. The trends of annual precipitation in the future

The result indicated four stations with significant positive trend with a 95% confidence interval under B1 scenario that one of these stations (Youngju) are located in the upstream of the basin. Other stations (Guchang, Hapchun, Masan) are detected in the downstream of the basin. Finally, under A1B scenario, the result indicated four stations with significant positive trend with a 95% confidence interval that are detected in the downstream of the basin as Guchang, Hapchun, Masan stations, and one of these Uljin is located in the upstream of the basin. Other the remaining stations under A2, B1, and A1B scenarios showed trend increasing with smaller than significant with of 95% confidence interval. In conclusions, the results of analysis detected that the downstream of basin will receives precipitation much more than upstream in Nakdong River Basin in ther future under all scenarios.

4.1. Change on the annual of precipitation

Figure 3a showed the results of the change in the annual precipitation in the baseline period and future periods under A2, B1, and A1B. In these, the mean annual of precipitation under all of scenarios showed more increase for all periods than baseline data. In specific of the precipitation, the analysis result under A2 scenario showed that the mean annual precipitation increased of +3.0%, +5.7% and +8.4% for periods as 2012-2040, 2041-2069, and 2070-2098, respectively. Under B1 scenario showed an increase of +6.1%, +5.9%, +9.8%; and A1B scenario as increasing of +5.5%, +3.5%, +11.7% in the same periods respectively.

4.2. Change on the seasons and months of precipitation

In term of seasons and months, the results also showed the change of the seasons of temperature. The results are summarized the changes in seasonal precipitation under A2, B1, and A1B scenarios. In particular, under of A2, B1, and A1B scenarios for period 2070-2098, the magnitude of the mean season precipitation indicated change of +5.4%, +3.5%, +9.9% in spring season; +12.6%, +18.3%, +19.4% in summer season; -8.9%, -7.2%, -8.1% in autumn season; +28.4%, +10.1%, +13.5% in winter season, respectively.

In addition, From figure 3b, 3c and 3d showed the change in the mean months of the precipitation under A1, B1, and A1B scenarios, respectively. The results showed an increase significantly of months in winter and summer. Specifically, it is highest variable about +15% to +30% in months of July, August, January, February, while it showed the reducing significantly about -10% to -40% in May, October in the most of periods under all scenarios. In conclusion, the results showed an increase in the mean annual precipitation for most of periods under all periods.

The mean seasonal and months of the precipitation showed an increase most of months in winter and summer season for all periods. On the other hand, in all of periods, the

results also showed the period of 2070-2098 surpassed in more increasing than other periods of the annual, seasonal and months for both of precipitation. The result of Mann-Kendall test also detected that the downstream of basin under most of scenarios will receive precipitation much more than upstream in Nakdong River Basin in the future.

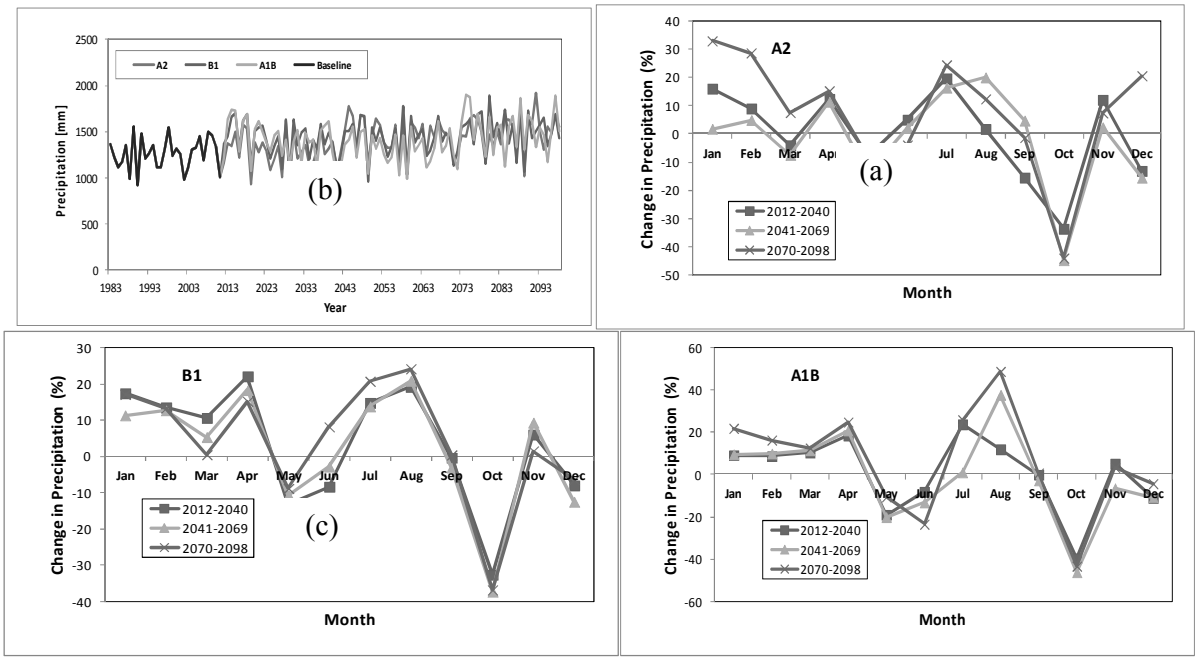


Figure 3. (a) Trend of annual precipitation under the A2, B1, A1B; (b, c, d) change of mean months precipitation for baseline and future periods under A2, B1, A1B scenarios

5. CONCLUSIONS

Climate change may seriously affect of regional water resources. Therefore, the objective of this study is focused on the using the Mann-Kendall test to identify of the climate variability trend on river basin. The results in this study showed an increase in the mean annual precipitation for most of periods under all periods. The mean seasonal and months of the precipitation showed an increase most of months in winter and summer season for all periods. On the other hand, the results also showed the period of 2070-2098 surpassed in more increasing than other periods of the annual, seasonal and months for both of precipitation. The result of Mann-Kendall test also detected that the downstream of basin under most of scenarios will receive precipitation much more than upstream in the future in study area. Climate changes impact on precipitation will affect more extreme events of flood and drought, water supply system, and especially agricultural production in the river basin. The results obtained with the Mann-Kendall tests showed agreement in their assessments of monthly, seasonal, and annual precipitation trends. The variability of negative and positive trends at various stations points to the need for more detailed studies on the climate change of this region. Specifically, it is highest variable about +15% to +30% in months of July, August, January, February, while it showed the reducing significantly about -10% to -40% in May, October in the most of periods under all scenarios. Moreover, the result of Mann-Kendall test also detected that the downstream of basin under most of scenarios will receive precipitation much more than upstream in Nakdong River Basin in the future. These results of study could be useful for planners and managers in water resources management in study area.

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Tóm tắt

PHÂN TÍCH VÀ NHẬN BIẾT XU HƯỚNG THAY ĐỔI LƯỢNG MƯA CỦA CÁC KỊCH BẢN BIẾN ĐỔI KHÍ HẬU SỬ DỤNG PHƯƠNG PHÁP MANN-KENDALL TRÊN LƯU VỰC SÔNG NAKDONG-HÀN QUỐC

Mục đích của nghiên cứu là phát hiện ra xu hướng của các chuỗi số liệu trong biến đổi khí hậu lưu vực sông Nakdong. Để đạt được mục tiêu nghiên cứu này phương pháp Mann-Kendall đã được sử dụng để rò tìm xu hướng thay đổi của chuỗi số liệu tại 16 trạm mưa trong vùng với số liệu mưa là 117 năm trong các kịch bản biến đổi khí hậu là A2, B1 và A1B. Kết quả nghiên cứu chỉ ra xu hướng chuỗi số liệu mưa tăng với độ tin cậy (chắc chắn xảy ra) đạt 95% dưới các kịch bản A2 là ba trạm, B1 là bốn trạm và A1B bốn trạm. Hơn nữa, kết quả đạt được với phương pháp Mann-Kendall cũng đã chỉ ra sự phù hợp về đánh giá xu hướng của mưa trong vùng theo tháng, theo mùa và theo hàng năm. Kết quả thể hiện tính chất thay đổi về xu hướng có sự tăng giảm tại vị trí các trạm rất cần thiết trong vùng rộng lớn chịu tác động của biến đổi khí hậu. Kết quả cũng đã phát hiện ra rằng trong các thập niên tới phần hạ lưu của lưu vực sông Nakdong sẽ có lượng mưa nhiều hơn lượng mưa phía thượng nguồn. Qua đó, kết quả nghiên cứu là cơ sở rất cần thiết và hữu ích cho các nhà quy hoach và quản lý tài nguyên nước trong lưu vực nghiên cứu.

Các từ khóa: Biến đổi khí hậu; phát hiện, rò tìm; phương pháp Mann-Kendall; sông Nakdong.

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