Evaluating Annual Rainfall Trends using Man-Kendall Test in Yom River Basin, Northern Thailand

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Keywords: Yom River Basin, Man-Kendall Test, Annual Rainfall

Abstract: In recent years, the influence of climate change and high rate of land use change has a matter of concern and may result in changing amount of annual rainfall in many areas. Yom river basin, one of major river draining to Chao Phaya river, has been flooded many times (i.e., 1995, 2002, 2006 and 2011) and has recently occurred more frequent. One of such problem may cause from climate and land use changes. The aim of this research was to analyze spatial and temporal changes in annual rainfall data collected from 1980 to 2010 in Yom river basin, covered areas approximately 23,948 square kilometers. The upper northern part of the area mainly consists of forest areas and partly agricultural area while the central and lower part mainly consists of agricultural and residential areas. Rainfall data derived from 43 stations was used in this paper; however, selected 37 stations that adequately provide more than 20-year rainfall data were chosen to be representative stations. The missing data of such representative stations was filled up using the inverse distance squared method and double mass analysis was also done to adjust the data for more reliability. To perform rainfall distribution, ten-years moving average and Man-Kendall test, were done to analyze the changes in annual rainfall throughout the basin. The results showed that the annual rainfall tend to increase more than 90% of rainfall stations and significantly increased in the central and lower parts (more than 10%). This would be applied for water resource managements, including both non-structural and structural measures, in such area.

1 INTRODUCTION

According to the report from Intergovernmental Panel on Climate Change [IPCC], the global temperature from 1956 to 2005 increased with the linear trend of 0.13 ºC per decade. There is high possibility that the increasing in the temperature has affected wind patterns and precipitation which causes rainfall to increase or decrease in some area (IPCC, 2007). In Thailand, annual mean temperature from 1981 to 2007 increased while from 1951 to 2005, there was a decreasing trend in rainfall (Bangkok Metropolitan Administration [BMA], Green Leaf Foundation [GLF] and United Nations Environment Programme [UNEP], 2009).

Urbanization is another factor that possibly affects rainfall (Chandler, 1965). Since 1960, Bangkok has grown rapidly. According to the data from Survey and Mapping Division, Department of City Planning, BMA, From 1968 to 2002, residential area grew from 181 to 366 square kilometer, commercial area grew from 18 to 61 square kilometer, agriculture area was reduced from 543 to 370 square kilometer, and vacant area was reduced from 624 to 379 square kilometer (BMA, GLF and UNEP, 2009).

This research investigated the change in rainfall in the inner part of Bangkok with the area of around 130 square kilometers as shown in Figure 1. The area covered both two sides of Chao Phraya River, the main river that passes through Bangkok. According to the land use plan developed by Department of City Planning, BMA (2006) shown in Figure 2, the western part is mainly consisted of residential areas with various densities while the eastern part is mainly consisted of commercial and residential areas with high densities.

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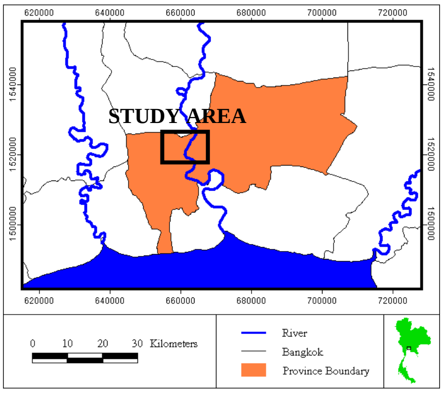

Figure 1 Study Area

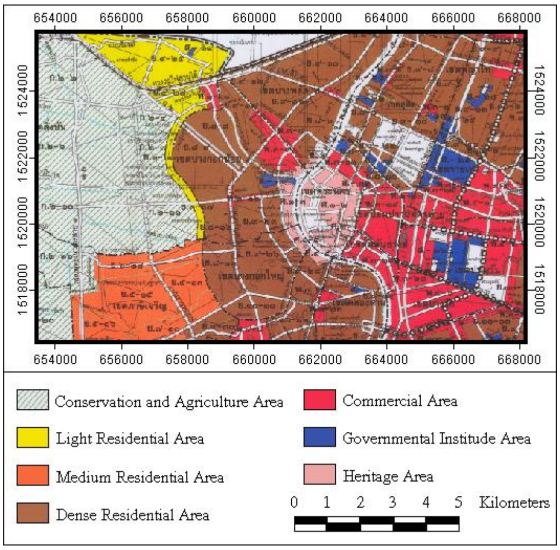

Figure 2 Land-use plan (BMA, 2006)

2 METHODS

This research investigated the change of a series of rainfall data collected by Thai Meteorological Department from 1982 to 2010 at the stations in the area. There have been many stations where daily rainfall data is collected, but only some of them are still in function while others have already been moved out. There are 32 stations the locations of which can be verified, so we used only the data from these stations for performing data analysis. However, only 15 of these stations are in the area and considered to have enough data to represent characteristics of rainfall in the area with the criteria of 60% in the western part and 75% in the eastern part. These 15 stations were chosen to be representative stations and are shown in Figure 3.

The missing data of such representative stations was filled up by the data from 5 stations which are closest to each representative station using inverse distance squared method (Thompson, 1999). However, at some representative stations with the missing data, the closest 5 stations of them also have no data, so it cannot be estimated. The years with the missing data that cannot be estimated in each station were left out from the investigation. After filling the missing data, double mass analysis was done to adjust the data for more reliability (Linsley et al., 1958).

In the investigation, annual rainfall was calculated by summation of daily rainfall in each year and maximum 1 day rainfall was determined by searching for the maximum of daily rainfall in each year. Table 1 shows the average annual rainfall and maximum 1 day rainfall in the study period.

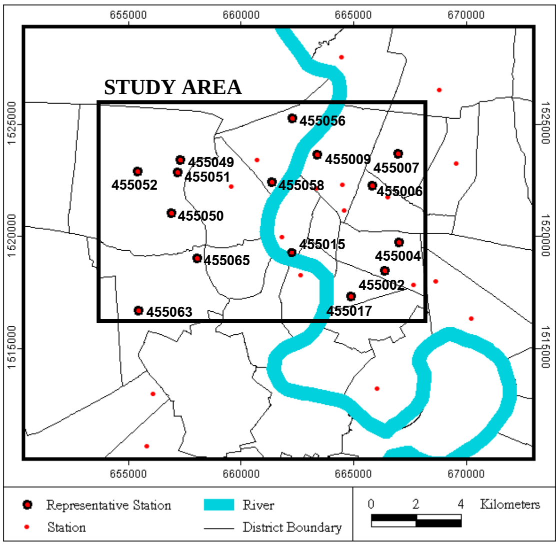

Figure 3 Rainfall stations in study area

Table 1: Average Annual Rainfall and Maximum 1 Day Rainfall

Station	Annual Rainfall (mm)	Maximum 1 Day Rainfall (mm)	Period
455002	1,605	101	1982-2008
455004	1,439	112	1982-2007
455006	1,272	92	1982-2009
455007	1,515	97	1982-2009
455009	1,581	96	1982-2009
455015	1,519	105	1982-2009

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455017	1,434	110	1982-2009
455049	1,310	82	1982-2010
455050	1,396	97	1982-2010
455051	1,248	78	1982-2010
455052	1,569	87	1982-2010
455056	1,408	86	1982-2010
455058	1,390	91	1982-2010
455063	1,427	91	1982-2010
455065	1,461	94	1982-2010

In the investigation of the trend of rainfall, Man-Kendall (MK) test (Mann, 1945; Kendall, 1975) against the null hypothesis that there is no change in the rainfall at the confidence interval of 10% was applied to investigate the direction of change in rainfall. In the method of MK test, the test statistics S is determined as follows,

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}\left(x_i - x_j\right) \tag{1}$$

Where n is number of data, x_i and x_j is the data at the time i and j, respectively, and sign function (sgn) is defined by

$$\operatorname{sgn}(x) = \begin{cases} 1 & ; x > 0 \\ 0 & ; x = 0 \\ -1 & ; x < 0 \end{cases} \tag{2}$$

When the number of the data (n) is the not less than 10, the distribution of the test statistics S is assumed to be normal with the mean ($E[S]$) and variance (Var(S)) as follows,

$$E[S] = 0 \tag{3}$$

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i (t_i - 1)(2t_i + 5)}{18} \tag{4}$$

Where m is the number of tied groups, and t_i is the data in the i^{th} tied group.

The test statistics S is standardized into Z by

$$Z = \frac{S - \operatorname{sgn}(S)}{\sqrt{Var(S)}} \tag{5}$$

The null hypothesis is rejected at a significant level of α when $|Z|$ is more than $Z_{1-0.5\alpha}$ of the standard normal distribution. A positive value of Z indicates an increasing trend while a negative value indicates a decreasing trend.

Even though the direction of change can be investigated by MK test, the magnitude of change still cannot be investigated, ten-years moving average (Subramanya, 2009) was applied to investigate the magnitude of change.

3 RESULTS

Figures 4-5 show the change of annual rainfall and maximum 1 day rainfall respectively. Arrows represent the direction of changes which are results of Man-Kendall test. The stations with no significant change are represented by dots. Numbers near the arrows and the dots are magnitudes of changes which are results from the moving average.

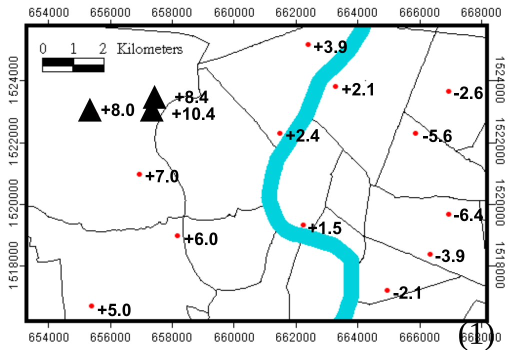

Figure 4 Change in annual rainfall (percent per decade)

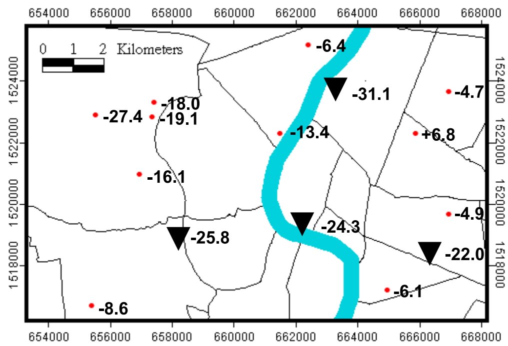

Figure 5 Change of maximum 1 day rainfall (percent per decade)

According to the Figure 4, the annual rainfall increased significantly in the northwestern part of the area. It also increased in the other western part and decreased in the eastern part, but without significance, and according to the Figure 5, the maximum 1 day rainfall decreased all most all over the area.

4 DISCUSSION

The non-uniformed trend of the annual rainfall is appeared to be related to the non-uniformed urbanization, since it suits with the land use data quite well. There was a significant increase in the north western part which is the agriculture and conservation area. There was also a non-significant increase trend in the south western part of the area which is a non-dense residential area. Even though the increasing was not significant, its magnitude

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was more than that in the eastern part. Along the river with the land use of the dense residential area, there was a slightly non-significantly increasing trend. And in the commercial area in the eastern part there was a non-significantly decreasing trend. However, the mechanisms of the urbanization that affect the rainfall are complex and vary with the features of cities (Shepherd and Burian, 2003), for example, in Ankara, urbanization seems to cause an increasing in convectional precipitation in the urban area (Çiçek and Turkoglu, 2005) which is contrast to our finding in the inner Bangkok that the rainfall decreased in the area of high urbanization. Further studies are needed in order to find the mechanism of the change of annual rainfall in the study area.

The decreasing trend of maximum 1 day rainfall seems to suit with the decreasing trend of rainfall in Thailand. From the daily rainfall data, we noticed that most of the rainfall and most days of the maximum rainfall for each year are in the southwest monsoon period. It is suggested that there was a reduction in strength of the southwest monsoon which was caused by shift in Walker circulation because there has been a negative relationship between Thailand monsoon rainfall and the El Niño-Southern Oscillation [ENSO] since 1980 (Singhratina et al., 2005). The finding of a decreasing trend in summer rainfall in the Yellow River Basin, China which is in the southwest monsoon period while there was an increasing trend in winter and spring rainfall (Hu et al., 2011) has also supported that the suggestion that the cause of the change in the maximum 1 day rainfall should be related with the southwest monsoon.

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