Comparative study of rainfall change in the north of Thailand

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Abstract: *The availability of water in the Chao Phraya delta in the dry season is much dependent upon run-off into the Bhumipol and Sirikit dams, and in particular on rainfall. This paper analyses the change of rainfall trend for all river basins in the north of Thailand. These basins comprise of Salawin, Kok, Ping, Wang, Yom, and Nan river basins. Analyses include tendency of both sub-basin and main system for each basin. Forty-seven years of annual rainfall between 1951 to 1997 from reliable rainfall stations were used in the calculation. The series of annual rainfalls and their moving average values were analyzed by two approaches: trend of rainfall and the shift in rainfall quantities. The analyses were carried out using hypothesis testing and the T-test. Results from previous study using annual rainfall data up to 1991 that showed tendency of rainfall recession and downward shift in annual rainfall for many basins are also compared. Results from both studies showed that rainfall recession existed in Kok, Ping and Nan basins. The moving average technique proved to be valuable method in removing the effect of cycle for annual rainfall. In addition, there was no change in both annual and monthly temperature and no relation between change of rainfall and temperature seemed to exist.*

1 Introduction

Rainfall is a major factor for planning and management of irrigation project and agricultural production such as reservoir operation, irrigation area, and irrigation water requirement. The rainfall change especially the reduction in annual rainfall may have a great effect on the effectiveness and accuracy on planning of irrigation project. In all regions of Thailand, the majority of population relies largely on agricultural sector including the north region. Moreover, the river basins in the north namely, Ping, Wang, Yom, and Nan contribute water supply for both north and central regions. Therefore, the change or reduction in rainfall may have a great effect on the country economy since the Chao Phraya basin which is the most productive for rice cultivation in the country receives most of its water from Bhumibol and Sirikit Dams especially for the dry season.

A research conducted at Asian Institute of Technology more than 10 years ago using rainfall record of about 50 years indicated that there was no change in rainfall structure for Thailand. However, in the last two decade it was observed that the drought had occurred more often

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than the past. Few publications showed the evident and proved statistically about the tendency of rainfall and its distribution. Akkanwanich (1995) studied the distribution and trend of drought in northeast Thailand. The author classified the drought condition for the most sensitive area into 4 zones i.e. Chaiyapum, Khonkaen, Nakhonratchasima and Loei Provinces and the wet area in Nakhonphanom and Nongkhai Provinces. Furthermore, the record from 40 rainfall stations had shown that the rainfall recession was about 2.47 mm/year. Kwanyuen (1998) reported the decrease of annual rainfall ranging from 2 to 6 mm/year in the central plain river basins from 86 rainfall stations. Moreover, rainfall distribution expressed in term of number of rainy day and rainfall intensity were also slightly change in some areas. Kwanyuen (2000) demonstrated a slightly reduction of annual rainfall and annual number of rainy day in the northeast region using data from 126 rainfalls during 1952-1998. These rainfall recessions occur mostly in the western part of the region range from 1 to 4 mm/year.

The change of in quantity and distribution of annual rainfall will directly effect the availability of water. Therefore, it is important to know whether there is a reduction in rainfall quantity so the information can be used for adjusting the planning and management of irrigation project and water resources related issues. This study analyzes the tendency of rainfall from 101 rainfall stations in Salawin basin, Kok basin, Ping basin, Wang basin, Yom basin, and Nan basin (see Figure 1) and each basin comprises of 19, 12, 25, 9, 15, and 21 rainfall stations, respectively. Result from this study will be compared with the previous analysis using data during 1952 to 1991. In addition, the analyses also extend to relation between the change of annual rainfall and pattern of rainfall distribution.

2 Characteristics of river basins and climatic conditions

The north of Thailand consists of 6 river basins: Salawin, Kok, Ping, Wang, Yom, and Nan basins. It also includes a part of Khong basin that will be excluded from this study. The total drainage areas are approximately 17920, 7895, 33898, 10790, 23615, and 34330 square kilometers, respectively. The basins are in the tropical monsoon zone subjected to the southwest monsoon during May to October and subjected to the tropical cyclonic storm from South China Sea during the end of rainy season between September and October. The annual rainfall of Salawin and Kok basins varies between 1000 and 2000 mm/year and the average annual rainfall is about 1100 to 1600 mm/year. The annual rainfall of Ping, Wang, Yom, and Nan basins is slightly lower between 700 and 1600 mm/year with the average annual rainfall of 900 to 1400 mm/year. Due to its location in tropical latitude, temperature is uniform throughout the year with very little seasonal variation around the mean of 28 °C. The average temperature at the hottest month (April) is about 32 °C and the average temperature at the coldest month (December) is about 25 °C.

3 Methodology

In this study, the trend of rainfall and its distribution are investigated and the results of data from 1952-1991 and 1951-1997 are compared. The procedures to analyze these data are similar in each basin and sub-basin and may be summarized as follows:

1. The rainfall stations and their records are investigated to select the rainfall stations that have long and rather complete records that are appropriate for the analyses. Forty-seven years of record from 1951 to 1997 are used in the study. In case of rainfall records at some stations have missing values or short records, these data are estimated by transferring information from nearby stations with complete or large records. The method is based on simple linear regression model, which is the most commonly used model for transferring hydrological information between stations. In this study, the hydrological model, HEC4 was used as a tool to estimated the required values.

2. The second step is to estimate the annual equivalent uniform depth using Thiessen Polygon method that is suitable for the topography of study area which can be classified as plain and mountain area with non-uniform rain gauge station.

3. The next step is to test influences about slope whether the regression lines ($y=\alpha+\beta x$) of the annual rainfall of real data have a zero slope. The T-test is applied for this case since the data have standard normal distribution. The hypothesis is two ways test (H0: $\beta = 0$; H1: $\beta \neq 0$) at .05 significant level. Then the test for shift or change in mean value is implemented using F-test with the hypothesis H0: $\mu_1 = \mu_2$; H1: $\mu_1 \neq \mu_2$ at .05 significant level. In order to select the critical year, data are divided into two groups and tested repeatedly from 1971 to 1982. For example, the first comparison is between annual rainfalls of 1951-1970 and 1971-1997 and the twelfth or the last comparison is between annual rainfalls of 1952-1981 and 1982-1997.

4. The results of annual rainfall of the real data of 1952-1991 from the previous study (Kanchanalekha, 1997) are compared to the result in this study.

5. Then the annual rainfalls evaluated by moving average method at 3, 4, 5, 6, 7, and 8 years are generated from the raw rainfall data.

6. The moving average data are tested for the tendency of data and shift in mean value with similar procedures as in step 3.

7. Finally, the changes in annual and monthly temperature are investigated. Then the changes in rainfall distribution according to the number of rainy day and rainfall intensity are investigated according to the boundary of province area rather than the boundary of basin area.

4 Results of the study

4.1 Trend of annual rainfall

The analyses from previous study using data from 1952 to 1991 show that there are mixed result of constant and recession trend of these basins. Similarly, there are also mixed results of constant and downward shift in annual rainfall. The results of last study and this study are presented together in table1. For Salawin, Ping, Yom and Nan basins, the tendencies are the same for both sets of data. For Kok and Wang basins, the tendencies are mixed between constant and recession depending on the variation of data. Nevertheless, the result from long record (1951-1997) may be better representation. Therefore, primary observations are that the trend for annual rainfall of Salawin, Wang and Yom basins is constant, there is a recession trend on annual rainfall of Kok, Ping and Nan basins, and finally a downward shift in mean value occurs at Kok and Yom basins.

From the analyses of real annual rainfall data for the whole basin using data from 1951 to 1997, there is no change in annual rainfall for Salawin, Wang and Yom basins. But there are relatively moderate recession trends for Ping and Nan basins and significant decrease trend in Kok basin. Considering the shift in mean value, there is no shift for Salawin, Ping, Wang, and Nan basins. Nevertheless, there is a downward shift for Kok and Yom basins. Figure 2 shows the recession tendency of annual rainfall for Kok basin.

Figure 2 Trend for annual rainfall of Kok basin

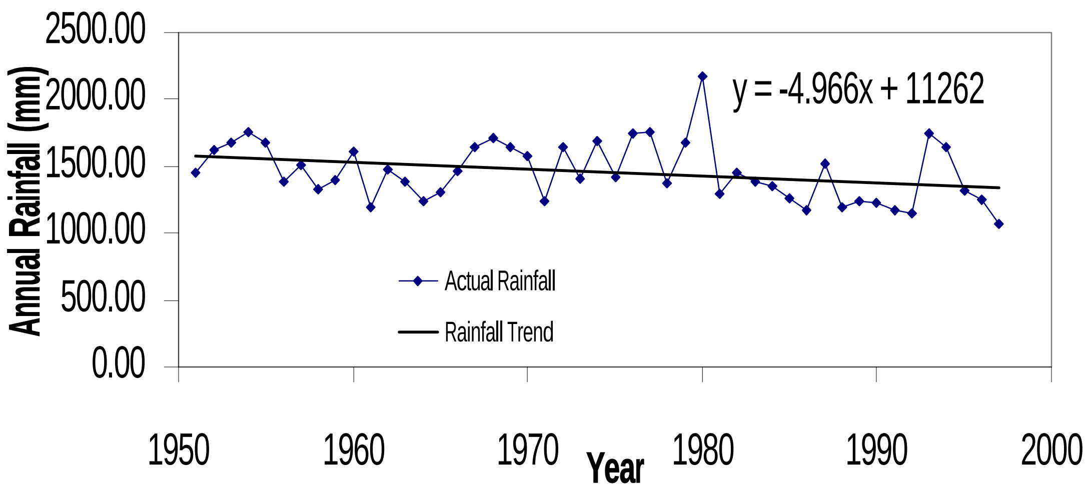

Table 1 Summary result for annual rainfall tendency of the whole basin

Basin	Previous (1952-1991)		Present (1951-1997)	
	Rainfall Trend	Shift in Mean	Rainfall Trend	Shift in Mean
Salawin	Constant	No	Constant	No
Kok	Constant	Downward	Recession (5.53)*	Downward
Ping	Recession (2.82)*	Downward	Recession (2.84)*	No
Wang	Recession (3.71)*	Downward	Constant	No
Yom	Constant	Downward	Constant	Downward
Nan	Recession (3.03)*	No	Recession (2.42)*	No

Note : * ( ) Rainfall recession in mm/year

By using moving average technique, six new data sets are generated from the original annual rainfall for 3, 4, 5, 6, 7 and 8 years moving average. Then these data are evaluated on the annual rainfall tendency and shift in mean value using the same procedure applied for the original annual rainfall. Results from the analyses are summarized in table 2 and 3.

Table 2 Summary results on tendency of moving average data of annual rainfall

Basin	Real Data	MA-3	MA-4	MA-5	MA-6	MA-7	MA-8
Salawin	C	C	C	C	C	R (0.92)	R (0.91)
Kok	R (5.53)	R (4.65)	R (4.45)	R (4.40)	R (4.45)	R (4.31)	R (4.16)
Ping	R (2.84)	R (1.76)	R (1.57)	R (1.43)	R (1.39)	R (1.14)	C
Wang	C	C	C	C	C	C	C
Yom	C	R (1.67)	R (1.52)	R (1.51)	R (1.69)	R (1.79)	R (1.87)
Nan	R (2.42)	R (1.79)	R (1.71)	R (1.89)	R (2.18)	R (2.33)	R (2.47)

Note : MA = Moving Average, C = Constant, R (x) = Recession in x mm/year

Table 3 Summary results on shift in mean of moving average data of annual rainfall

Basin	Real Data	MA-3	MA-4	MA-5	MA-6	MA-7	MA-8
Salawin	No	Yes	Yes	Yes	Yes	Yes	Yes
Kok	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ping	No	No	Yes	Yes	Yes	Yes	Yes
Wang	No	No	No	Yes	Yes	Yes	No
Yom	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Nan	No	Yes	Yes	Yes	Yes	Yes	Yes

From the analyses on tendency of moving average data for the main basin, it is found that generally the moving average data will give similar result to the real data e.g. Kok, Ping, Wang, and Nan basins. However, for Salawin and Yom basins, the tendency may be identified using moving average technique. The reason is that the moving average method can remove or reduce the effect on the cycle of the data. From the analyses on shift in mean of moving average data for the main basin, it is also found that normally the moving average data will give same result to the real data e.g. Kok and Yom basins. Nevertheless, for Salawin, Ping and Nan basins, the shift in mean can be identified using moving average technique by the same reason.

Most of the basins are relatively large, therefore they are divided into sub-basin and data from these smaller areas are also analyzed. For Salawin basin located in the northwest of the region that consists of 17 small sub-basins, the tendency for sub-basins are constant for all sub-basins. For Kok basin, the smallest basin located in the north of the region that consists of 4 small sub-basins, the tendency is generally the same as the main basin. In detail, there are relatively large decrease in annual rainfall ranging from 5 to 8 mm/year in 3 sub-basins and constant for only 1 sub-basin. For Ping basin, a large basin located in the western part of the region that consists of 16 sub-basins, although the main basin has a recession in annual rainfall but the majority of sub-basins have no change in annual rainfall. In detail, the upper and lower parts (10 sub-basins)have constant rainfall, the middle part has a recession trend about 3 to 4 mm/year. For Wang basin, a small basin located in the middle of the region that consists of 7 sub-basins, all of them have a constant tendency. For Yom basin located in the southern part of the region that consists of 9 sub-basins, most of them have a constant tendency except one basin that has a small recession of 3 mm/year. For Nan basin, a large basin located in the east region that consists of 15 sub-basins, even though the main basin has a recession trend but most of the sub-basins have a constant tendency except Kwai Noi sub-basin that has a small recession of 2.5 mm/year. The area of sub-basins and results from the analyses of some selected basins such as Kok, Wang and Yom basins are presented in table 4.

Table 4 Summary data and results for sub-basins of Kok, Wang and Yom basins

Basin	Sub-basin	Area (km^2)	Rainfall Trend	Shift in Mean
Kok	1. Nam Kok	2770	Recession 7 mm	Yes
	2. Mae Fang	1945	Constant	No
	3. Mae Laos	2640	Recession 6 mm	Yes
	4. Mae Saruay	540	Recession 8 mm	Yes
Wang	1. Upper Wang	1687	Constant	No
	2. Mae Sai	743	Constant	No
	3. Nam Tui	801	Constant	No
	4. Middle Wang	2132	Constant	No
	5. Nam Jang	1600	Constant	No
	6. Nam Tum	738	Constant	No
	7. Lower Wang	3090	Constant	No
Yom	1. Upper Yom	2029	Constant	No
	2. Nam Duan	1945	Constant	No
	3. Nam Ngaw	1800	Constant	No
	4. Middle Yom	2588	Constant	No
	5. Mae Kammee	571	Constant	No
	6. Mae Ha	507	Constant	No
	7. Lower Yom	11287	Recession 3 mm	No
	8. Huai Mae Sin	610	Constant	No
	9. Mae Mok	2279	Constant	No

In general, there is no shift in mean annual rainfall for majority of the sub-basins of Salawin, Ping, Wang, Yom, and Nan basins. However, there is a significant downward shift in mean annual rainfall for most sub-basins of Kok basin. In addition, it is found that the results of moving average analyses for sub-basins are similar to the ones from the real annual rainfall data but the shift can be identified easier by the moving average as shown in the example of Yom basin in table 5.

Table 5 Results on tendency of moving average data of sub-basin of Yom basin

Yom Basin	Rainfall Trend (mm/year)							Shift in Mean
	Real	MA-3	MA-4	MA-5	MA-6	MA-7	MA-8	
Main Basin	C	R-2	R-2	R-2	R-2	R-2	R-2	Yes
1. Upper Yom	C	C	C	C	C	C	C	No
2. Nam Duan	C	C	C	C	C	C	C	No
3. Nam Ngaw	C	C	C	C	C	C	C	No
4. Middle Yom	C	C	C	C	C	C	C	No
5. Mae Kammee	C	C	C	C	C	C	C	No
6. Mae Ha	C	C	C	C	C	C	R-2	No
7. Lower Yom	R-3	R-3	R-2	R-2	R-2	R-3	R-3	No
8. Huai Mae Sin	C	C	C	C	C	C	C	No
9. Mae Mok	C	C	C	C	C	C	R-1	No

Note : MA = Moving Average, C = Constant, R = Recession

4.2 Trend of temperature

The analyses of temperature change and rainfall distribution for the basin are implemented only in some representative provinces as follows: Chiang Mai for Salawin basin; Chiang Rai for Kok basin; Chiang Mai and Lampoon for Ping basin; Lampang for Wang basin; Phrae and Phayao for Yom basin; and Nan and Pitsanulok for Nan basin.

The results show that monthly temperature is mostly constant for every month of all provinces. For annual temperature, there are mixed results of constant, decrease and increase trends for all basins. Nevertheless, these changes seem to be insignificant and there is no correlation between rainfall and temperature. It may conclude that a small change of annual temperature may be a periodic phenomenal or temporary change rather than a true trend.

4.3 Rainfall distribution

In this study, rainfall distribution is expressed in term of number of rainy day and its density distribution. Results show that the annual number of rainy day is constant for the majority of 6 provinces and slightly increase for the other 2 provinces. These changes are rather insignificant and there is no correlation between annual rainfall and number of rainy day. However, the monthly number of rainy day is varied among constant, decrease and increase as shown in table 6. In case of density distribution, there is no sign of change in rainfall pattern since the numbers of rainy day for all intensities are very much stable.

Table 6 Trend in monthly number of rainy day for basin in the north

Province	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chiang Mai	C	C	I	I	C	C	C	C	C	C	C	C	C
Chiang Rai	I	C	C	C	I	I	C	I	C	C	C	I	C
Lampoon	C	C	C	I	D	C	D	D	I	D	I	D	D
Lampang	C	C	C	C	C	C	D	C	C	D	C	C	C
Phrae	I	C	C	C	C	I	C	I	C	C	I	C	C
Phayao	C	C	I	I	D	D	I	I	I	D	I	C	D
Nan	C	C	C	C	C	I	D	C	C	D	C	C	C
Pitsanulok	C	C	C	D	C	C	C	C	C	D	I	C	C

Note : C= Constant, I = Increase, D =Decrease

5 Discussion

The analyses of rainfall change for the north of Thailand use rainfall data from 1951 to 1997 from rain gauge stations that their locations distribute through out the basin command area. Real annual rainfall data and their moving average data of 3, 4, 5, 6, 7, and 8 years are analyzed for all basins and sub-basins to identify trend of annual rainfall and shift in mean value. In addition, results using data during 1952-1991 from previous study and results using data during 1951-1997 from this study are compared. Finally, the analyses of temperature change and rainfall distribution employ the data based on provincial area according to the same system used by the Meteorological Department. The important characteristics of the main river basins and sub-basins may be summarized as follows:

For Salawin basin, there is no change in annual rainfall of the main basin and sub-basins. The shift in mean is not exist for the main basin but downward shift occurs in some sub-basins.

For Kok basin, there is a strong recession in annual rainfall for both main basin and sub-basin. These areas with recession cover about 75 percent of the total area of the basin. The downward shift in mean also occurs in the same area as the recession.

For Ping basin, there is a recession in annual rainfall of the main basin but the recession on the sub-basin occurs only at the middle part of the basin. The upper and lower parts of the basin have stable tendency. The downward shift only occurs in some sub-basins in the middle part of basin.

For Wang and Yom basins, there is no recession in annual rainfall for the main basin and sub-basins except a small recession in lower Yom sub-basin. The downward shift only exists in the main basin of the river.

Finally, for Nan basin, there is a recession in the main basin and Kwai Noi sub-basin. The downward shift occurs only in three sub-basins at the upper part of the basin.

Overall, a strong recession in annual rainfall may be observed in Kok basin and a small recession can also be observed in Ping and Nan basins. The conclusion from both data sets (1952-1991 and 1951-1997) are slightly different so the result from this study that has a more complete and longer record may be a better representation of the basin characteristics.

In most cases, results from the real annual data and the moving average data indicate similar tendency with a small variation of value. However, the moving average data may be a better representative in many cases since this technique can remove the cycle effect out from the data.

From the analyses, there is no sign of change for annual and monthly temperatures and structure of rainfall intensity. Therefore, the relation between the change of rainfall and temperature may not exist. In addition, there is no relation between the annual number of rainy day and the amount of annual rainfall.

6 Conclusions and recommendations

Some important conclusions that can be summarized from this study are as follows:

1. There is an evidence of annual rainfall recession in some river basins of the north region especially Kok, Ping and Nan basins. This recession is relatively strong in Kok basin. Downward shift is also noticed in the area of strong recession but it need to be proved whether there is a shift alone or there is a combination of recession and shift.

2. Results from the real value of annual rainfall and the moving average data are slightly different. Therefore, periodic or cycle of annual rainfall may exist and can partially remove by moving average technique.

3. Both annual and monthly temperature has stable tendency. Therefore, there may be no relation between rainfall recession and temperature change.

4. Rainfall distribution has no change and the reason for rainfall recession still have to be investigated.

The recession of annual rainfall in the north of Thailand is an important factor for availability of water supply for the north and central regions that must be considered in design, planning, operation, and management of water resources project. The future study should consider these changes in order to receive more accurate solutions of existing and new irrigation projects.

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