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ANALYSIS OF HISTORICAL CHANGES IN RAINFALL IN HUAI LUANG WATERSHED, THAILAND

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ABSTRACT

This study aims to investigate changes in rainfall in terms of trends, variability, spatial and temporal distributions, and extremes in the Huai Luang watershed. The trend analysis was applied to the time series of rainfall data for 32 years from 1982-2013. Changes in spatial and temporal rainfall distributions and extremes were investigated by comparing the 2 periods of the rainfall data between 1982-1997 and 1998-2013. Frequency analysis of annual maximum daily rainfall was applied to determine changes in extreme rainfall for different return periods at three stations located upstream, middle and downstream of the watershed. The results of this work show significantly increasing trends in annual rainfall, spatial variations and extreme daily rainfall in the Huai Luang watershed. The extreme rainfall resulted in increasing floods in last decade. Spatial and temporal rainfall distributions are also changing. The lower part of the watershed will have more rain. Further studies on potential impacts of rainfall changes on flood risk, water resources management, urbanization and agriculture development in the Huai Luang watershed are recommended to support preparation of adaptation strategies for mitigating potential negative impacts.

Keywords: Climate change; Extreme rainfall; Frequency analysis; Mekong; Trends

1. INTRODUCTION

Rainfall patterns in Thailand are influenced by two monsoons. The southwest monsoon, which typically occurs from May to October, brings a stream of warm moist air from the Indian Ocean towards Thailand causing abundant rain over the country. Rainfall during this period is not only caused by the southwest monsoon, but also by the Inter Tropical Convergence Zone (ITCZ) and tropical cyclones which produce a large amount of rainfall. The northeast monsoon, which typically starts in October and ends in February, brings cold and dry air from the anticyclone in the China mainland over major parts of Thailand, especially the Northern and Northeastern regions (Manisarn, 1995). The phenomenon of El Niño and La Niña also influence the amount

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of rainfall in this region. These events occur every three to eight years as a part of a natural cycle (Eso et al., 2015). The impacts of El Niño and La Niña cause extreme droughts and floods and severe environment, social and economic damage across the country as occurred in 2011 (extreme flood) and 2015 (extreme drought).

Rainfall is the most important natural factor that determines agricultural production and it plays an important role in the Thai economy (Paxson, 1992), particularly in the Northeast of Thailand. According to National Statistic Office, in 2011 over 40% of the country's labor force was employed in the agricultural sector. Most agricultural areas in the Northeast region are rain-fed crops which rely directly on the rainfall amount and distribution to support crop growth. Changes in rainfall directly impact on crop areas in terms of production and practice (TKK & SEA START RC, 2009). According to national policies, rapidly growing and expanding urban centers in this region, such as in Khon Kaen and Udon Thani, will increase water demands, pressure on water supply and competition for water allocation between urban and rural areas in the future.

Increasing temperature and changing rainfall patterns are now being recognized as the most important effects from climate change in most parts of the world. This has prompted public debate on the apparent increased frequency of extreme weather, and in particular, on perceived increases in rainfall intensities (IPCC, 2015; Santiboon, 2011). Consequently, these changes will affect the hydrological cycles, the environment and society. This study, therefore, aims to investigate changes in rainfall in terms of trends, variability, spatial and temporal distributions, and extremes in the Huai Luang watershed. Understanding historical changes in rainfall is importance for water resources management, urban planning and agriculture development in the Huai Luang watershed to assess current and potential impacts. The analyzed results can also support critical information in order to prepare adaptation strategies and measures to deal with these kinds of changes.

2. METHODOLOGY

2.1. Study Area

The Huai Luang watershed is located in Northeast Thailand (Figure 1). The watershed, including Huai Dan sub-watershed, drains an area of 4,122 km^2. The area covers Udon Thani, Nong Bua Lam Phu and Nong Kai Provinces. The elevation of the basin ranges from 631 to 153 m above mean sea level. Huai Luang River is a tributary of Mekong River. With a length of 149.7 km, Huai Luang River originates in Phu Phan Mountains, passes through Udon Thani city, and joins the Mekong River in Phoanpisai District, Nong Kai Province. The average monthly temperature for 30 years (1981–2010) varies from 16.3°C to 36.3°C. Annual rainfall over the watershed varies from 1,145–2,174 mm which results in an annual average of 1,564 mm. Based on the 2009 land use map from the Land Development Department, Thailand, the watershed was dominated by agriculture (68%), while forest and urban area covered 14% and 6%, respectively, of the total area.

2.2. Data Used and Methods

Daily rainfall data from 1982–2013 (32 years) at seven stations were selected for analysis in this study. The location of selected rainfall stations is presented in Figure 1. The data were obtained from the Thai Meteorological Department, Thailand. The trend analysis applied here was an attempt to fit the linear models to the time series of average annual rainfall for 32 years. The standard deviation was used to represent spatial variability of annual rainfall among the selected seven rainfall stations.

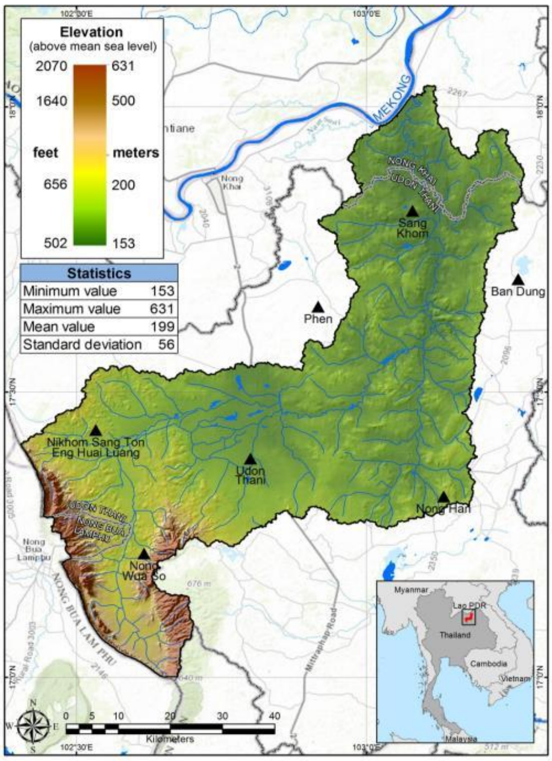

Figure 1 Huai Luang Watershed and rainfall stations

Changes in spatial and temporal rainfall distributions and extremes were investigated by comparing the two periods of the rainfall data between 1982–1997 (16 years) and 1998–2013 (16 years). Changes in spatial rainfall distributions over the Huai Luang watershed were examined based on the average annual rainfall and a spline interpolation technique. Average monthly rainfall was used to determine changes in temporal rainfall distribution. Frequency analysis of annual maximum daily rainfall was applied to determine changes in extreme rainfall at three stations located upstream (Nong Wua So), middle stream (Udon Thani) and downstream (Sang Khom) of the watershed. Gumbel distribution was selected for frequency analysis of the extreme values.

3. RESULTS AND DISCUSSION

3.1. Changes in Trends and Variability

The time series of annual average areal rainfall is plotted in Figure 2. Trend analysis was applied to annual average areal rainfall and it showed a significant rising trend during the observed period from the years 1982 to 2013. The values of average annual rainfall during 1982–1997 and 1998–2013 are1415.8 mm 1711.7 mm, respectively. It is clear that the average annual rainfall in the second period has increased by 20% from the first period. This significant change also results in increasing severe floods in the Huai Luang watershed in the last decade. Based on a recently study from Royal Irrigation Department (RID), Thailand, it was shown that there were extreme floods occurring in this watershed during the second period in 2000–2001 and 2010–2011. The 2000 flood caused 1,505 million baht of damage to Udon Thani city and farmland and the 2011 flood caused damage to 51,327 households and 230 km^2 of paddy field (RID, 2015). According to trend analysis using a linear regression method, the annual rainfall is estimated to increase to 2000 mm in 2020 which is an increase of 16.8% from the average annual rainfall during 1998–2013. These findings can be useful information for disaster preparedness to prevent and mitigate larger flood events in the near future.

The time series of annual rainfall of the seven rainfall stations are also plotted to present rainfall variation across the Huai Luang watershed. The spatial variation of annual rainfall also showed an increasing trend. Variability of annual rainfall among the seven rainfall stations from the average value is about ± 250 mm during 1982–1993 and it increases to ± 500 mm in the present time.

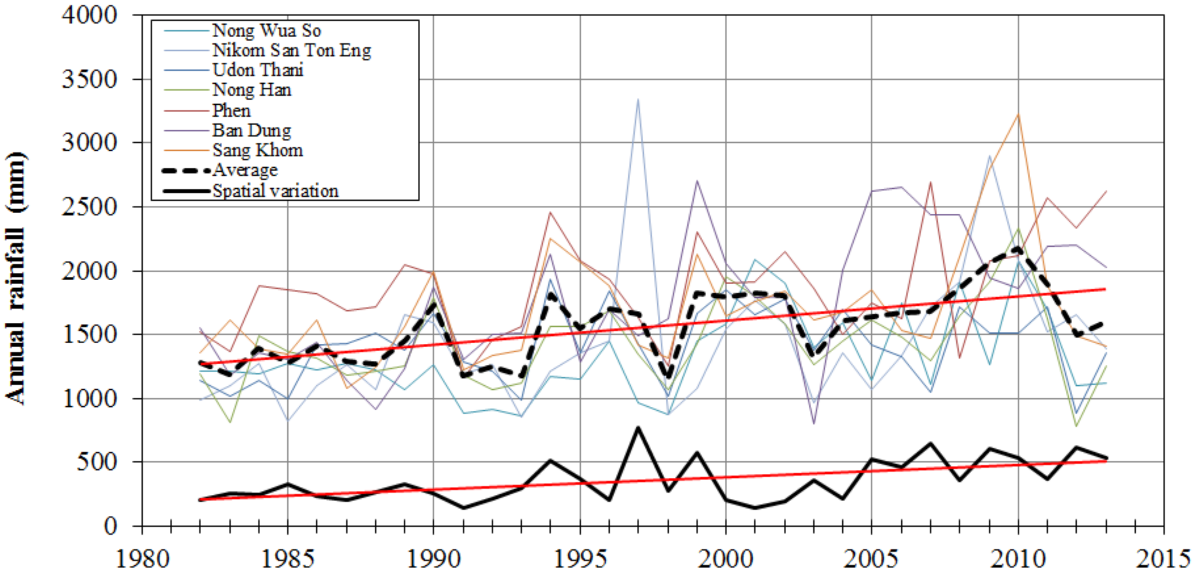

Figure 2 Trend analyses of annual average areal rainfall and spatial variation

3.2. Changes in Spatial and Temporal Distributions

A comparison of spatial patterns of average annual rainfall distribution between 1982–1997 and 1998–2013 is presented in Figures 3a and 3b.

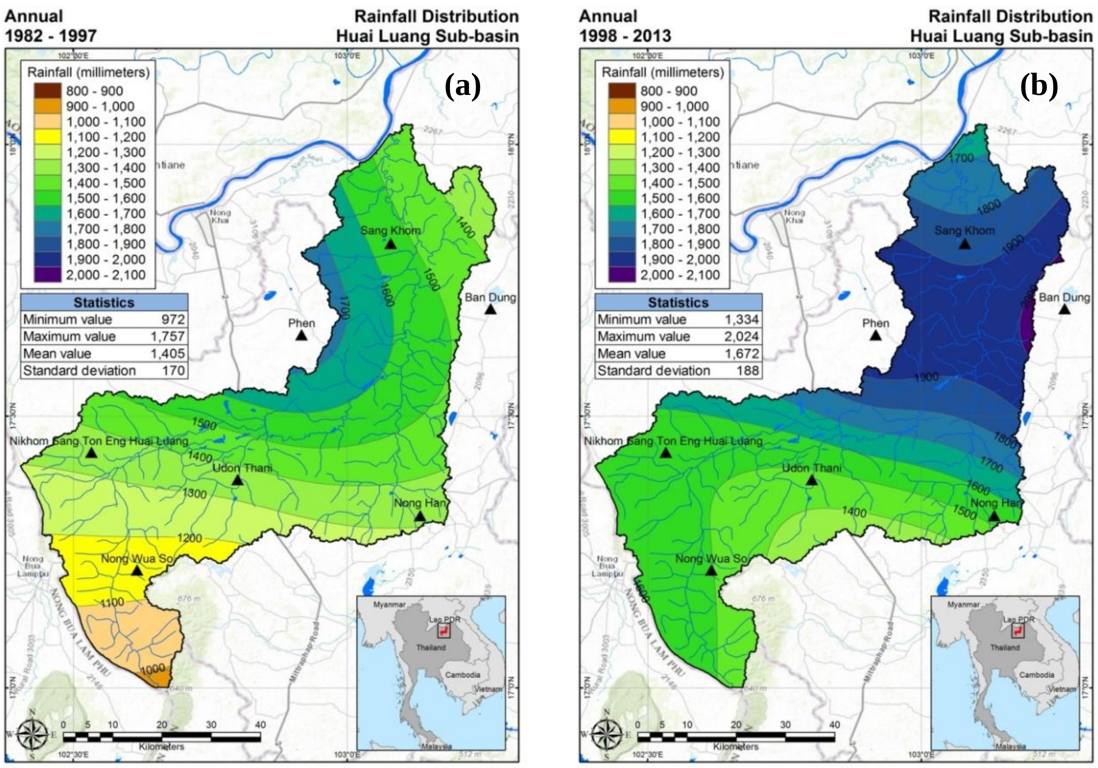

Figure 3 Comparison of spatial rainfall distribution between 1982-1997 (a) and 1998-2013(b)

According to Figure 3, we found that the spatial distribution of average annual rainfall between those two periods is different. Average annual rainfall during 1982–1997 (Figure 3a) increases from east to west while average annual rainfall during 1998–2013 (Figure 3b) increases from north to south. Particularly in the southern part of the watershed, the magnitude of average annual rainfall during 1998–2013 is higher than that of the period 1982–1997 by about 300 mm.

The average monthly rainfall of the seven rainfall stations during 1982–1997 and 1998–2013 is compared in Figure 4 to investigate changes in temporal rainfall distribution.

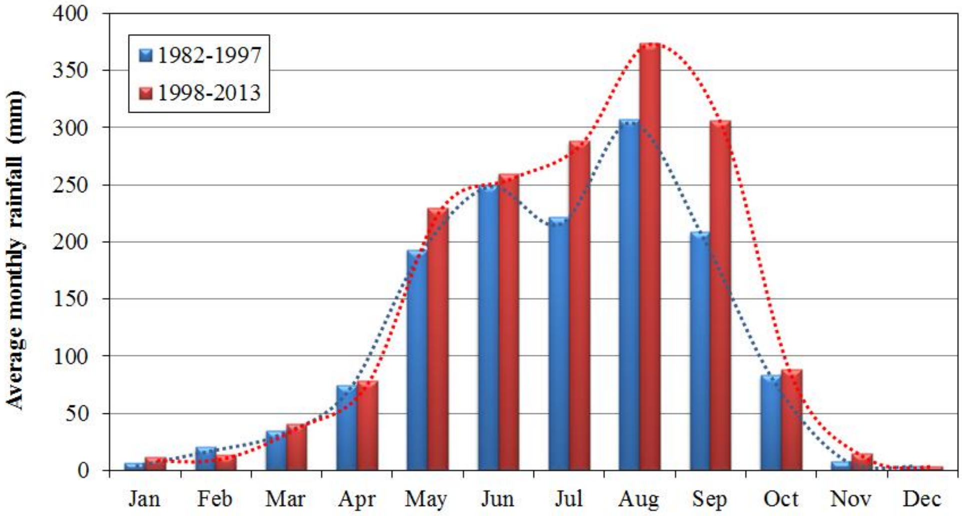

Figure 4 Comparison of monthly rainfall distribution between 1982–1997 and 1998–2013

Differences in temporal rainfall distribution between those two periods is found in the wet season during May to October. There are two peaks of average monthly rainfall distribution in June and August during 1982–1997 but the average monthly rainfall distribution has changed to one peak in August during 1998–2013. During the period of 1982–1997, the average monthly rainfall in July is lower than in June because the prevailing southwest monsoon over the Andaman Sea and Thailand is weak and the monsoon trough moved from place to place over the southern portion of China. The amount of rainfall in July–Sep during 1998–2013 increased considerably compared to the amount of rainfall during 1982–1997 because the number of tropical storms that passed through North–Eastern region of Thailand during 1998–2013 is higher than the period of 1982–1997 as shown in Figures 5a and 5b.

3.3. Changes in Extremes

Results of frequency analysis of annual maximum daily rainfall at three stations in the upstream (Nong Wua So), middle stream (Udon Thani) and downstream (Sang Khom) of the watershed are presented in Table 1 and Figures 6a, 6b and 6c, respectively. Annual maximum daily rainfall data for different return periods (5 years to 20 years) during 1982–1997 and 1998–2013 were calculated. The percentage differences of annual maximum daily rainfall between those two periods are determined and given in Table 1. Figure 6 indicates that the annual maximum daily rainfall during 1998–2013 was higher than the annual maximum daily rainfall during 1982–1997 for all three stations and all return periods. The extreme daily rainfall increases 28.09–39.82% in the upstream, 33.85–45.76% in the middle stream and 19.22–19.88% in the downstream of the Huai Luang watershed. These results are consistent with the previous studies in North-Eastern region of Thailand (Endo et al., 2009; Limsakul et al., 2007).

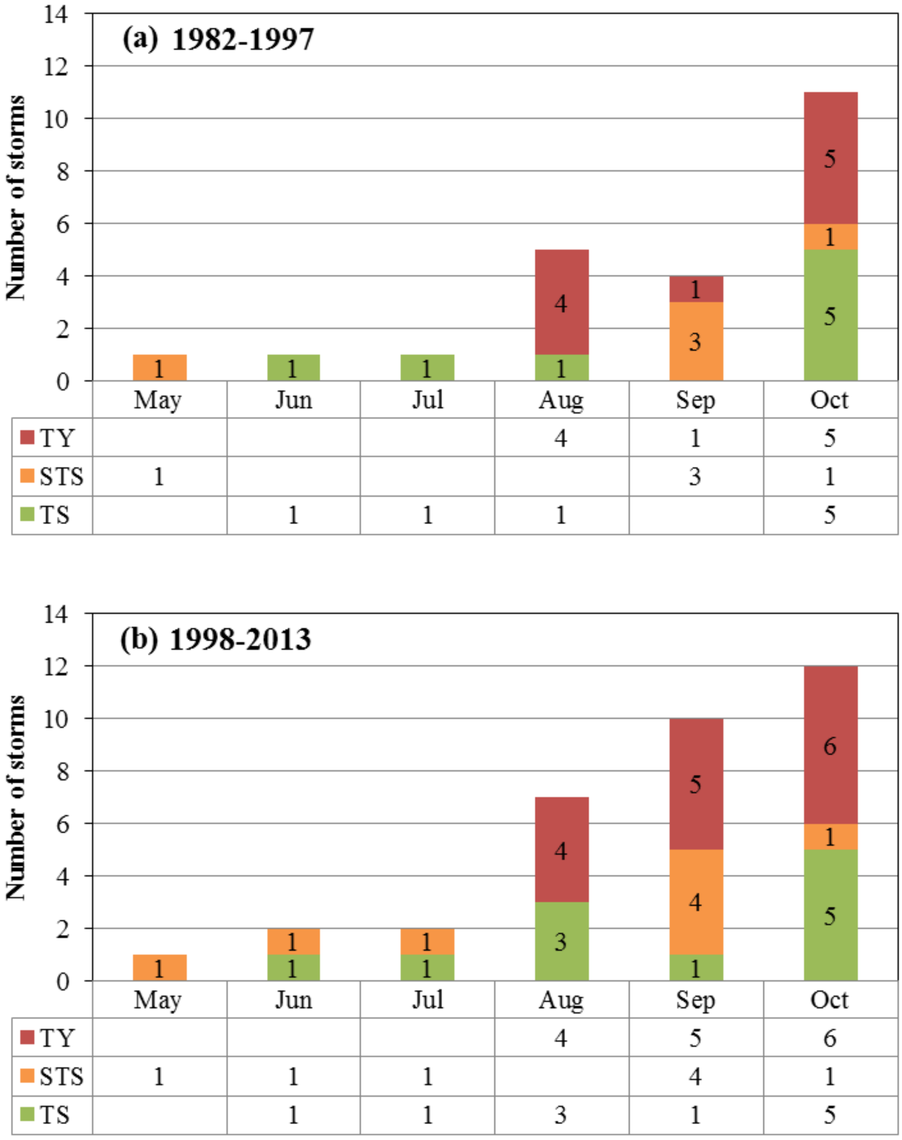

Figure 5 Comparison of a number of storms between 1982–1997 and 1998–2013: Typhoon (TY), Severe Topical Storm and Tropical Storm (TS)

Table 1 Comparison of annual maximum daily rainfall for different return periods

Return Period	Nong Wua So			Udon Thani			Sang Khom		
	1982-1997	1997-2013	% Diff	1982-1997	1997-2013	% Diff	1982-1997	1997-2013	% Diff
5 years	109.8	140.7	28.09	119.3	159.7	33.85	122.7	147.1	19.88
10 years	132.1	178.3	34.94	146.1	205.8	40.90	152.8	182.6	19.48
15 years	145.2	200.3	37.98	161.8	232.8	43.94	170.4	203.3	19.32
20 years	154.4	215.9	39.82	172.9	252.0	45.76	182.9	218.0	19.22

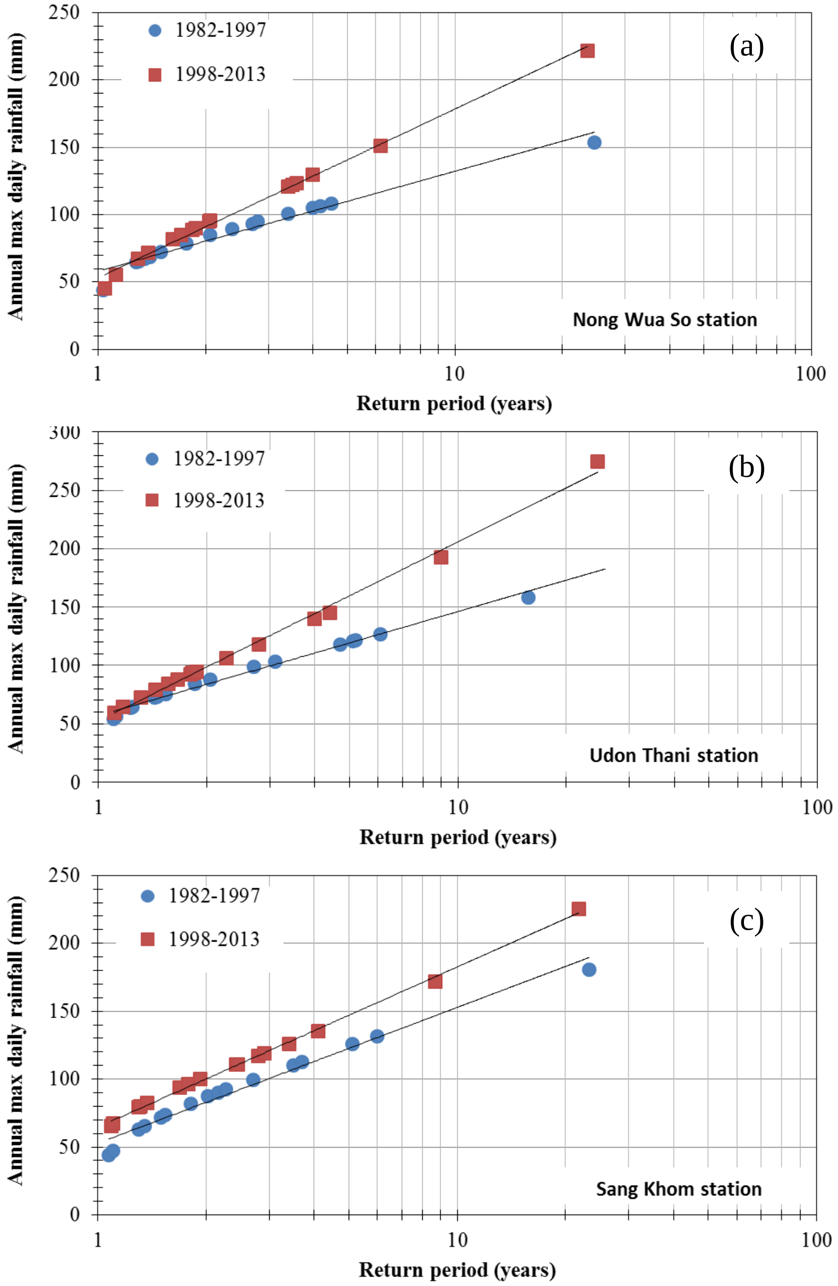

Figure 6 Comparison of frequency distribution of annual maximum daily rainfall between 1982–1997 and 1998–2013 at: (a) Nong Wua So station; (b) Udon Thani station; and (c) Sang Khom station

4. CONCLUSION

Annual rainfall data collected over the Huai Luang watershed shows an increasing trend during 32 year-period from 1982–2013. The annual rainfall during the second period (1998–2013) is higher than the first period (1982–1997) by 20%. The magnitude of extreme daily rainfall at three monitoring stations in the second period is also higher than the first period by 19.22–45.76% for 20 years return period (Table 1). It is evident from a recently study that severe floods in this watershed occurred more frequently during 1998–2013. Therefore, it can be concluded that increasing trends in annual and extreme daily rainfall lead to an increased flood risk in the Huai Luang watershed. Moreover, the annual rainfall is predicted to continue to increase by 16.8% in 2020 which could cause bigger flood events in the near future.

It was found that the annual rainfall variation is also increasing. The variation of annual rainfall has double increased from ± 250 mm during 1982–1993 to ± 500 mm during 1998–2013. The study results show that spatial and temporal rainfall distributions between those two periods are different. The lower part of the watershed will have more rain. These findings indicate that rainfall patterns in the Huai Luang watershed is increasingly becoming uncertain and unpredictable.

Further detailed studies on potential impacts of rainfall changes on flood risk, water resources management, urbanization and agriculture development in the Huai Luang watershed are recommended in order to support information for disaster preparedness and adaptation strategies for mitigating potential negative impacts.

5. ACKNOWLEDGEMENT

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