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Assessment of Rainfall Change in Kampong Thom Province: Implication on Agriculture and Infrastructure

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Abstract: *As a consequence of the global warming effects on rainfall changes such as droughts, hail storm or flash flood, data sets of highest daily rainfall for the period (1981-2010) were used for calculating the statistical distribution of extreme monthly rainfall in tributary of Tonle Sap Basin (Stung Chinit Catchment, Kampong Thom Province). The main objective of this paper is to develop the return period of rainfall and estimate depth of rainfall from 2010 to 2040 by following the scenario A2 and evaluating the frequency of rainfall maximum intensity. The frequency analyses and most statistical test had been done by using HYFRAN Model. Three distributions were used in this research namely Lognormal, 3-parameter lognormal and Gumbel. Estimation of theoretical distribution was achieved by using maximum likelihood method and adequacy test was carried out through chi-square test. The result shows that annual rainfall intensity does not extremely change from 2010 to 2040. However, it just only changes in duration of rainfall. In the past, the peak of rainfall was in September and October, but in the future, the peak of rainfall will be in June and July and the maximum rainfall intensity is 155 mm for a return period of 100 year. The changing to time and intensity rainfall will affect to agriculture and infrastructure can be trigger a chain of negative leading to loss livelihood. Finally, the study suggests measures for enhancing community's capacity for adaptation to current climate variability and future climate change.*

Keyword: Stung Chinit Catchment, rainfall change, HYFRAN, statistical distribution

1. INTRODUCTION

Rainfall is a limited and important hydrological variable in dry land areas. The need for water in these areas increases daily due to population growth, economic developments, urbanization. As consequently, water management using all the available resources is becoming increasing crucially (Emori and Brown 2005). In order to develop an effective management strategy, it is paramount to understand and assess the impact of water on the ecosystem. The study and understanding of climate, variation of rainfall, period and amounts of rainfall and its associated effects on the ecosystem is vital. Plant productivity in these dry areas is primarily limited by the availability of adequate water.

Rainfall is one of the principal controlling elements in agriculture. The success of crop establishment and growth depends largely on the availability of adequate rainfall. The amount of rainfall on particular area determines the type of agriculture that can be carried out and the crop that can be cultivated in a region. For agriculture, important aspects which are related to rainfall include the days of the start and the end of rainy season, its length, plus rainfall amounts and the risk of dry spell within the season.

Quantification of the rain intensity is generally done by using model HYFRAN statistical analysis software with fit Lognormal, 3-parameter lognormal and Gumbel to find the annual maximum intensity series in Stung Chinit Catchment.

In this we analyzed the characteristics of rainfall in Stung Chinit Catchment by using data recorded between 1981 and 2010. Then, future data rainfall between 2010 and 2040 was estimated by Climate Change, Agriculture and Food Security. The questions addressed are as follows: Are the rainfall patterns stable or variable? The ability to shed light on these questions is essential in the long-term economic and environmental planning for Stung Chinit catchment.

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The main objective of this research is to assess frequency of rainfall data using HYFRAN case study in Stung Chinit catchment.

2. METHODOLOGY

2.1. Study area

This research was conducted in Chinit Catchment which mainly in Kampong Thom Province, Central of Cambodia. It is about 178 Km from Phnom Penh City and about 85km from Kampong Thom Town. The studied Catchment area covered 4214.12 Km^2 shown in figure 1.1. However, the area is mainly in Santuk District and Sandan District, Kampong Thom Province. The climate is affected by two monsoons, the cool with dry north eastern monsoon from November to March and the humid south western monsoon from May to October.

Chnit Catchment is mainly agricultural production. The Royal Government of Cambodia (RGC) recognized that agricultural and rural development were key to increase sustainable economic growth in Cambodia (ADB.2009) . Key area in Chinit Catchment identified for improving agricultural productivity include (i) providing and properly maintaining critical infrastructure for irrigation, drainage, and rural transport; (ii) strengthening agricultural research and extension; (iii) enhanced income opportunities for farm households by diversifying crops.

According to the Water Year Book of Mekong River Committee data sources, the basin's climatic parameters recorded at Kampong Thmar station are: an average annual temperature of 27.8 °C with a minimum of 26.2 °C in December and maximum of 29.8 °C in March, and the average annual rainfall recorded 1,590 mm with heavy rains recorded from April to October. The records of the agro-meteorological group in research and technology development division from FAO showed that the sunshine hours as 7.3 hours per day and the solar radiation at an annual average of 19.5 MJ/m2 per day.

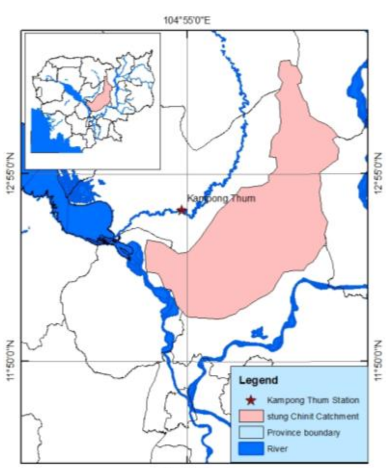

Figure 1.1 Study area: Stung Chinit Catchment

2.2. Data description

The rain gauge monitoring, 485523.97m of easting (102.5E of longitude) and 1403963.93m of northing (12.5N of latitude) and ele1vation 13m, was installed in Kampong Thom Province by the Ministry of Water Resources and Meteorology, which the data was recorded over the 30 years from 1981 to 2010. The observe data during 30 years past were used as the baseline compare to future data set forecasting for climate change in Chinit Catchment.

Furthermore, future data rainfall from 2010 to 2040 in Stung Chinit Catchment (Kampong Thom Province), which is located in the latitude of 12.503°, the longitude of 105.149° and elevation 16 m, was estimated by CCAFS (Climate Change, Agriculture Food Security) using special report on emission scenario (SRES) by following Scenario A2. Data source estimated of daily rainfall from 2010 to 2040 of MarkSimTM GCM-DSSAT weather file generator.

Scenario A2, one of scenarios in the SRES, was developed by considering various possible futures development such factors economic development, technological development, energy use, population change, and land-use change (Nakicenovic et al., 2000). Scenario A2 was focused on cumulative CO_2 emissions are about 575 and 870 ppm, respectively while current concentration of CO2 is about 380 ppm.

2.3. HYFRAN model

HYFRAN model is software used to fit statically distributions. It includes a number of powerful, flexible, user-friendly mathematical tools that useful for the statistical analysis of extreme events. It can be a perform basic analysis for any time series of independent and identically distribution data.

It was developed by INRS-BE of Canada and it is very friendly software endowed with remarkable numerical and graphic tool. There are not less that 12 statistical laws. The model can allow the comparison of fitting results with various statistical distributions on the same data set. The comparison of fitting function based on a number of parameter of the fitted probability distribution and the confidence interval.

2.4. Frequency analysis

HYFRAN model is a frequency analysis tool, assessments of the probability in future events based on the analysis of historical rainfall records. The estimation of rainfall depth for selected probability or return periods are required for the design of drainage, sewer system or floodplain protection. The annul maximum daily rainfall recorded in 24 hours used to determination of rainfall depth that can be expected for selected return period. The analyst consists in collecting historical data over an adequate number of years by ranking the data by estimating the probability of non exceedance with selected method.

2.5. *Data analysis*

The data entered into spreadsheet of the program; HYFRAN, the frequency analysis is the ranking of the rainfall data (Hassoun.2011). After the rainfall data are ranked as a series data set, subsequently the probability have to be defined of rainfall depth.

The data input in HYFRAN model was used maximum rainfall in 24 hours in yearly of data set.

Empirical non-exccedance probability was calculated by using Weibul formula in equation 1 :

$$F[x[k]] = P = k/(n+1) \qquad \text{(e.q.1)}$$

Where, k=rank of maximum rainfall in 24 hours amount of data set and n= number of observations, and for Weibul a=0

The probability is an estimate of the probability of exceedance that the corresponding to rainfall depth shown in e.q.2 and e.q.3. When data are ranked from the lowest to highest values, the probability refer to the probability of non-exceedance. Hence, the probabilities are estimates of cumulative probabilities. By summing the probabilities of occurrence of all events greater then (probability of exceedance) or less than (probability of non-exceedance) some given rainfall depth. Since probabilities are unknown the probabilities of exceedance have to be estimated by selected method for non-exceedance probability.

$$T = 1/P \qquad \text{(e.q.2)}$$

$$T = 1/(1-q) \qquad \text{(e.q.3)}$$

Where,

P is probability of exceedance (that an event of specified depth and duration will be exceeded in a year)
T is return Period (average length of time between events of a given depth and duration)
q is non- exceedance probability

Then the probability distribution was analyzed in order to determine which of these best describe the maximum annual rainfall intensity variations. At the beginning, all available probability functions in the HYFRAN software (Lognormal, 3-parameter lognormal and Gumbel) were considered. Moreover, to better identify the law that best describes the variation of precipitation and adequacy, Chi-squared test were employed.

Statistical analysis of the data series of annual maximum intensity has revealed that probability functions that best describe the variation are lognormal distribution, 3-parameter lognormal distribution and Gumbel distribution.

Lognormal distribution: The lognormal distribution or also known as Gaussian distribution is applied to asymmetrically distribution data. Besides, it is also referred as the bell curve due to the bell shape of distribution (K waku and Duke, 2007). The lognormal distribution can be specified by two parameter, namely mean (μ) and standard deviation (σ). The data will fall between two real number with non-zero over the entire line. The probability distribution function of lognormal distribution can be determined by using the e.q.4.

$$f(x) = \frac{1}{x\sigma\sqrt{2\pi}} \exp\left\{-\frac{(\ln x - \mu)^2}{2\sigma^2}\right\} \qquad \text{(e.q.4)}$$

Where:
n = Number of observation
μ = Mean
σ = Standard deviation

3-parameter distribution: The 3-parameter distribution is applied to asymmetrically distribution data can be determined by using the e.q.5.

$$f(x) = \frac{1}{(x-m)\sigma\sqrt{2\pi}} \exp\left\{-\frac{(\ln(x-m) - \mu)^2}{2\sigma^2}\right\} \qquad \text{(e.q.5)}$$

Where:
n = Number of observation
μ = Mean
σ = Standard deviation
x = values are the times-to-failure

Gumbel distribution: The Gumbel distribution is also called the log-Weibull distribution and the double exponential, although the term “double exponential” is also used as another name for the Laplace distribution. The probability distribution function of Gumbel distribution can be determined by using the e.q.6.

$$f(x) = \frac{1}{\alpha} \exp\left\{-\frac{x-u}{\alpha} - \exp\left[-\frac{x-u}{\alpha}\right]\right\} \qquad \text{(e.q.6)}$$

Where:
n = Number of observation
μ = Mean
σ = Standard deviation
x = values are the times-to-failure

3. RESULTS AND DISCUSSION

3.1. Rain day

A day is considered rainy when rainfall is greater than 1 mm. The annual rainy days for the geographical locations and Stung Chinit are presented in Figure 3.1. The average number of rainy days per year from 1981-2010 for Stung Chinit was 108 days. The highest number of rainy days of 131, 122, 121, 121 and 118 days were recorded in 1999, 2002, 1993, 1994 and 1985, respectively. The minimum of rainy day was 79 days in 1987. Moreover, the future rainy day will be estimated from 2010 to 2040 by forecasting model under scenario A2. The number of rainy day in future day is fluctuated between 103 to 108 days per year. The average number of rainy days per year from 2010-2040 for Stung Chinit is 105 days.

3.2. Annual rainfall

There is a high correlation between annual rainy days in the real data and future data, which are not extremely different (Fowler and Kilsby.2004). Moreover, the annual rainfall as depicted in Figure 3.2. is also not extremely different. The patterns are quite similar and indicate that a high number of rainy days usually result in a high annual rainfall.

The annual rainfall in Kampong Thom province illustrated in Figure 3.2. has increased steadily from one decade to another decade. Based on the depth of rainfall observed, it is projected that the highest of rainfall of 1939 mm, 1865 mm, 1832 mm, 1798 mm were recorded in 2006, 1994, 1986, and 1996, respectively. In 1990 and 1997, the low of annual rainfall height was about 994.4 mm and 1085.2 mm only. The data has estimated under the scenario A2, which is expected that the annual rainfall will have decreased gradually. The trends of change in the amount rainfall could be described as increasing from 1504.3mm to 1556.93mm. As a result, annual rainfall slightly change, particular in 2010-2040. Unpredictable changes in rainfall condition, i.e. flood, drought and other natural shock could have adversely affected to the Tonle Sap Basin.

3.3. Maximum daily rainfall

Maximum daily rainfall is an important indicator of flash flood hazards. Stung Chinit is characterized by highly diverse low and extreme heavy rainfall as shown in Figure 3.3 the highest daily maximum rainfall of 147.4mm was recorded in 1998. The next six highest daily values of 119, 115.1, 106.5, 119.8, 136.4 and 131.4 mm occurred in 1982, 1984, 1994, 2006, 2008 and 2009, accordingly. There is no pattern to maximum rainfall over the year. Nine maximum daily rainfalls of greater than 100mm were recorded in the station from 1980 to 2010. The maximum daily rainfall in future data was estimated that it would be lesser than 100 mm from 2010 to 2040. However, such high estimating of greater than 100 mm of daily rainfall are 109.60, 109.30 and 110.60 in 2036, 2037 and 2038.

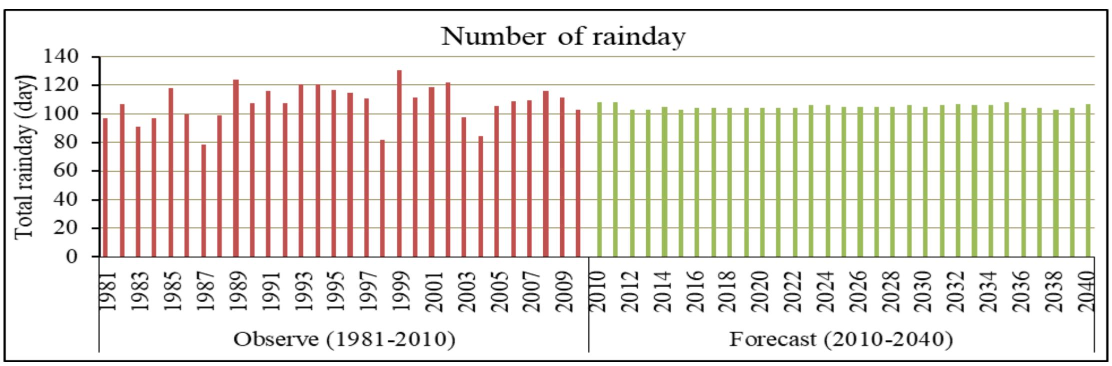

Figure 3.1. Number of Rain days

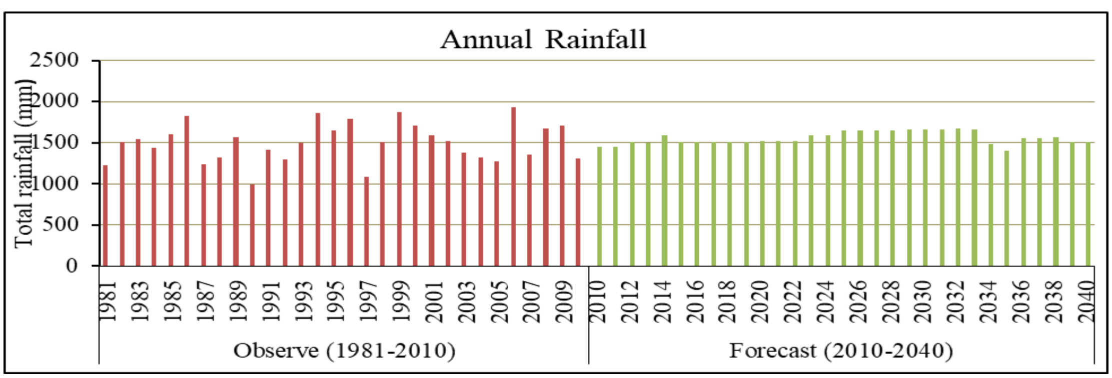

Figure 3.2. Annual rainfall

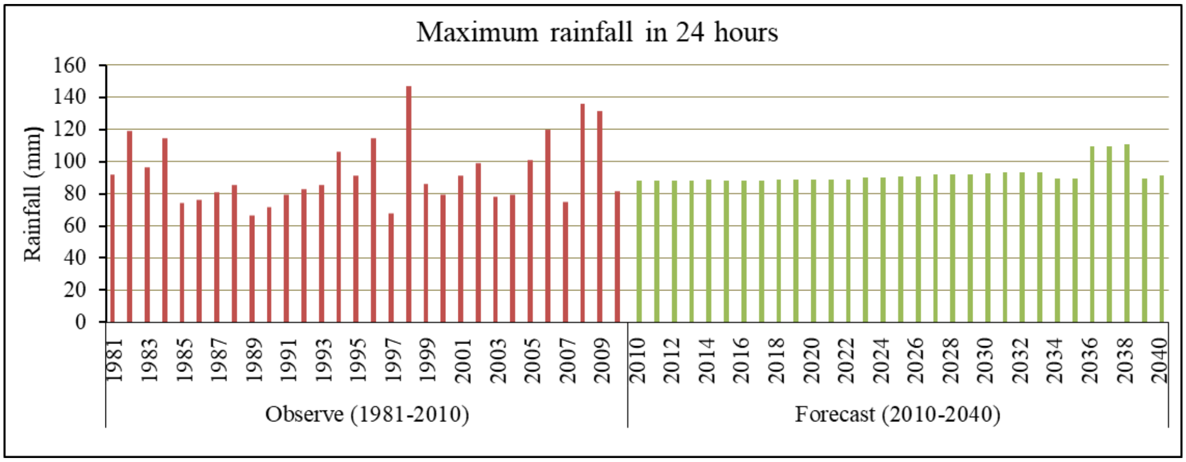

Figure 3.3. Maximum rainfall in 24 hours

3.4. Seasonality of rainfall

Monthly rainfall was also analyzed from 1981 to 2010 and from 2010 to 2040 (shown in figure 3.4a). From 1981 to 2010 monthly in Kampong Thom Province, the highest rainfall was in September and October. These top ranking shifted to June and July in the 2010-2040. The rainfall pattern has also changed. In the 1981-2010, it was bi-modal with peaks in September and October, but in 2010-2040 the peak was in June and July. Analysis of season, wet season was still from May to October and dry season was from November to April. Comparing the annual mean rainfall for the 1981-2010 and for the 2010-2040 by estimating the trends of change in the annual rainfall could be described as increasing from 1,504 mm to 1,556 mm.

The figure 3.4b shows that dry and wet season were 224.54 mm (15%) 1,279.8 mm (85%), respectively, for the year 1981 to 2010 periods. For the 2010 to 2040 period, the rainfall was 104.9 mm (7%) in dry season and 1,452 mm (93%) in wet season, respectively. The annual rainfall intensities decreased with a decrease of rainfall in dry season resulting in a higher proportion of rainfall during the wet season (Nakicenovic et al., 2000). As the result, the concentration of rainfall in the wet season is likely to have affected the amount of water and flow regime of stream in the Stung Chint Catchment.

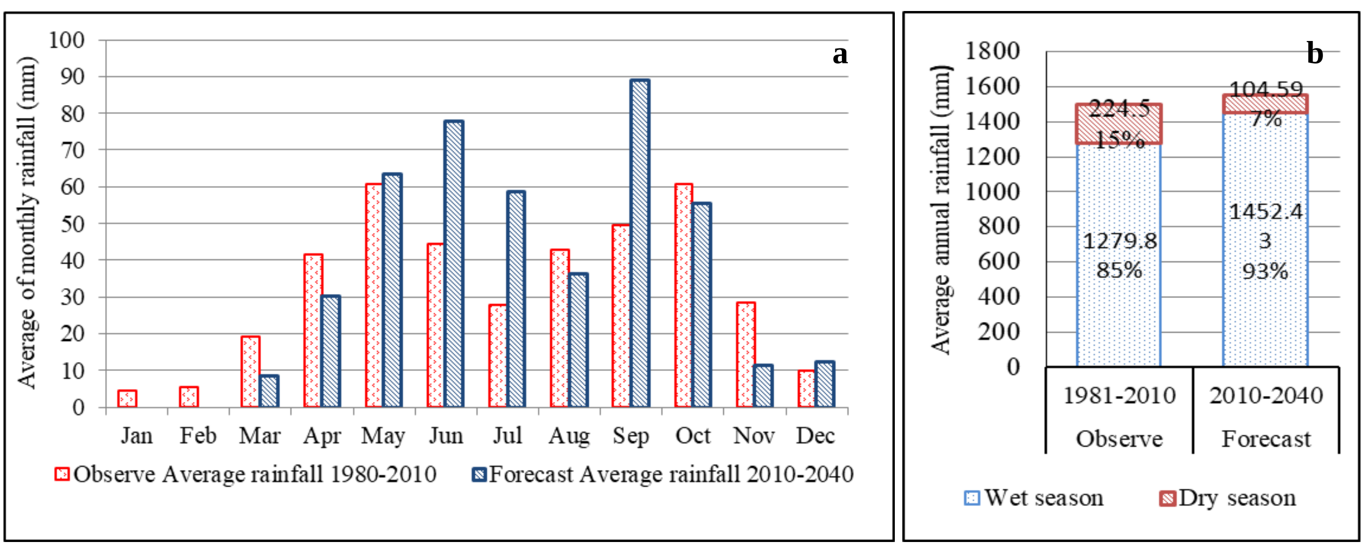

Figure 3.4. Trends in mean rainfall in the 1980-2010 and 2010-2040: (a) monthly mean rainfall (arrows indicate increasing or decreasing monthly mean rainfall), (b) seasonal and annual mean rainfall (sum of two seasons).

3.5. Probability analysis of extreme rainfall

The HYFRAN software can implement estimation for a large number of non-standard statistical distributions. The study of maximum annual rainfall in 24 hours using three statistic distributions was selected for representing the probability analyses of extreme rainfall in Kampong Thom Province from 1981 to 2010, which were used Lognormal, 3-parameter lognormal and Gumbel and using (95%) confidence interval.

Comparing criteria on the three statistic distributions above, the result leading to conclude that Gumbel distribution is the best fitting for estimating the maximum daily rainfall. The maximum of daily rainfall calculated for different return periods according to Gumbel distribution and Figure 3.7 shows the extreme analyst of maximum daily rainfall by using Gumbel distribution.

Table 3.1 Fitting modes with estimate parameter

No	Distributions	Estimated parameter
1	Lognormal	U=4.502, sigma=0.210
2	3-parameter lognormal	m=59.195, U=3.372 sigma=0.603
3	Gumbel	U=84.483, alpha=15.292

The extreme rainfalls were estimated via thirty-year yearly maximum rainfall data (1981-2010). The best fit distribution for estimating the extreme rainfall is selected according to the fitting functions shown in table 3.1. This study used, Lognormal in figure 3.5, Three-parameter lognormal shown in the figure 3.6 and Gumbel distribution which are the best fit distribution are recommended shown in figure 3.7.

The statistic value for independence of the probability were identified the significant value (p) in the statistic measures whether the given hypothesis is probably true or not due to change. If the significant value that is p<0.05, the null hypothesis is (Ho) can be reject at a significant level of 5%. The significant value (p) that >0.05 or 5% indicates that the data are independence.

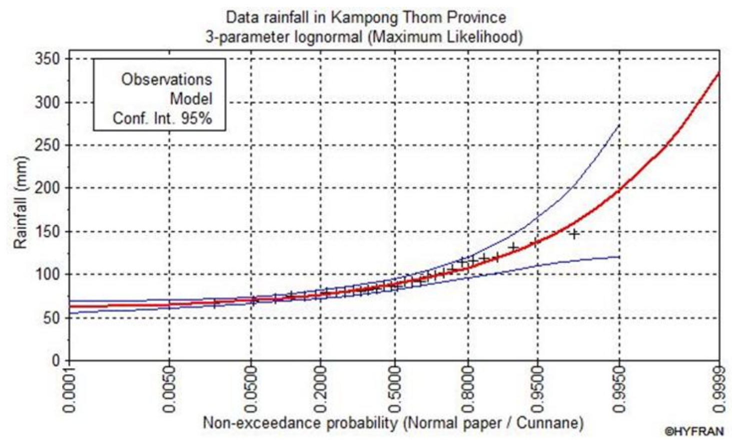

Figure 3.6. Estimation curve of rainfall for thirty year by using 3-parameter lognormal distribution

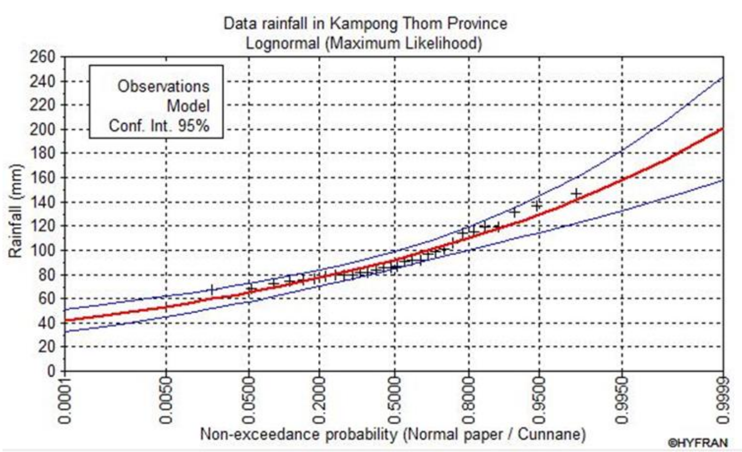

Figure 3.5. Estimation curve of rainfall for thirty year using Lognormal distribution

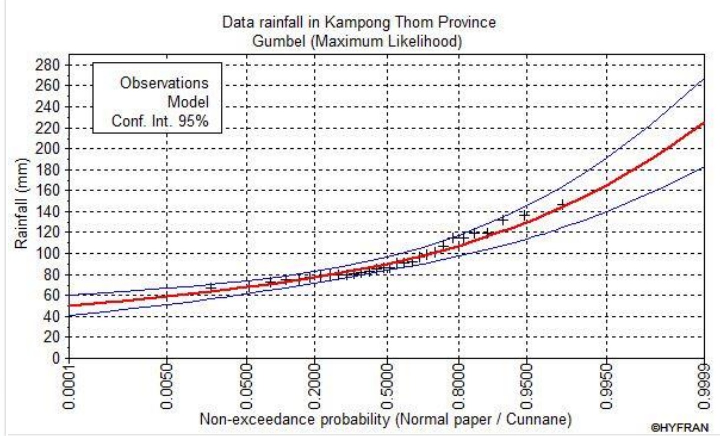

Figure 3.7. Estimation curve of rainfall for thirty year by using Gumbel distribution

The comparison criteria of the three statistic distributions above are the result leading to conclude that Gumbel distribution is the best fitting for estimating the maximum daily rainfall. Table 3.2 presents estimates of annual maximum daily rainfall calculated for different return periods according to Gumbel distribution and Figure 4. 6c show the extreme analyst of maximum daily rainfall by using Gumbel distribution.

Table 3. 2 Estimation of maximum daily rainfall intensity by using Gumbel distribution.

Return period (years)	100	50	30	20	10	5	3	2
Rainfall intensity (mm/day)	155	144	141	130	119	107	98	90

4. CONCLUSIONS AND RECOMMENDATION

4.1 Conclusion

The result from the research of rainfall data from 1981 to 2010 and the result of data analysis of rainfall by scenario A2 to estimate daily rainfall from 2010 to 2040 show that:

- The number of rainy days that was estimated by mean model under scenario A2 is slightly decrease comparing to real data.
- The annual rainfall intensity in future slightly increases from 1504 mm to 1556 mm, but in dry season decrease from 15% to 7%.
- The duration of rainfall in future have changed from maximum in September to maximum in July.
- The maximum daily rainfall is up to 155 mm for 100 year of return period.

The results obtained from this study are important for designing storm intensity for a given period of recurrence that was estimated in the region. Furthermore, the result can be a key for developing irrigation system and infrastructure in Kampong Thom Province. It is therefore recommended that both structure and institutional measures can employ as a mean for climate risk reduction and for improved resilience of agricultural and infrastructure.

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