Proceedings of the 11th World Congress on New Technologies (NewTech'25)
Paris, France - August, 2025
Paper No. ICCEIA 126
DOI: 10.11159/icceia25.126

Assessment of Extreme Rainfall in Chiang Mai Utilizing the ACER Method

Chana Sinsabvarodom[1,*], Thirasak Panyaphirawat[1], Damrongsak Rinchumphu[1], Pheerawat Plangoen[1] and Phattrawich Namracha[1]
[1] Department of Civil Engineering, Faculty of Engineering, Chiang Mai University
239, Huay Kaew Road, Muang District, Chiang Mai, Thailand
chana.sinsabvarodom@cmu.ac.th ; thirasak_p@cmu.ac.th ; damrongsak.r@cmu.ac.th ;
pheerawat.p@cmu.ac.th; phattrawich_namracha@cmu.ac.th

Abstract
Extreme rainfall is customarily utilized as fundamental data in the design of hydraulic structures. The precision of rainfall estimation corresponding to the return periods is crucial for the economic viability, structural integrity, and safety of such designs. Traditionally, a range of classical extreme value (EV) models are employed to facilitate the estimation of extreme rainfall events. The objective of the present study is to employ the average conditional exceedance rate (ACER) method for the purpose of estimating extreme rainfall patterns in Chiang Mai, Thailand. The ACER method is conventionally applied to derive extreme values from time series data and is typically employed in the field of ocean research. In this research, long-term rainfall data from 1999 to 2022 were collected from rainfall gauge stations managed by the Meteorological Department of Thailand. The results conclusively demonstrate that the ACER method yields highly consistent estimations of extreme rainfall. Consequently, these estimations hold significant relevance for informing the design and construction of hydraulic structures.

***Keywords*:** Extreme Rainfall, Extreme Value Analysis, Rainfall Estimation.

1. Introduction
The assessment of extreme values is of significant importance across various domains in water engineering and beyond. Extreme value theory (EVT) constitutes a substantial body of literature that encompasses a wide array of disciplines, theories, and practical applications [1]. It has become a primary focus in climatology owning to the potentially hazardous nature [2, 3]. In recent times, there has been a marked increase in focus on extreme events within the realm of climate change. Among the prevailing theories is the widely accepted hypothesis suggesting a forthcoming rise in extreme events due to the escalation of climatic variability [4, 5].

Additionally, extreme value theory (EVT) has been extensively conducted on precipitation extremes, particularly in relation to rainfall, owning to their significant impact on the occurrence of floods. For more detailed information, you can refer to a review of the statistical methods for extreme value analysis in hydrology and climatology by Climate Data and Monitoring (Guidelines on Analysis of Extremes in a changing climate, [6]), Katz, Parlange and Naveau [7], Papalexiou and Koutsoyiannis [8] and Papalexiou, Koutsoyiannis and Makropoulos [9].

Thailand has a history of frequently encountering severe weather conditions, particularly natural disasters resulting from heavy rainfall. These events typically include occurrences like flash floods and landslides, leading to extensive human and property losses [10]. The primary triggers for severe flooding in Thailand's central region are the extreme precipitation events in the upper northern region. These events often persist for several consecutive days during the rainy season, which spans from the middle of May to the middle of October each year. The year 2011 marked a particularly devastating period, as Thailand experienced its most severe flood in half a century [11]. Over two-thirds of the central region was affected, with total rainfall during the 2011 rainy season reaching 1,439 mm, equivalent to 143% of the average rainfall between 1982 and 2002 [12]. This flood inflicted significant damage, resulting in 813 fatalities and 3 people reported missing nationwide. The affected agricultural land area across Thailand reached its peak on November and the estimated total flood volume amounted to billions of cubic meters [11].

The objective of this research is to apply the Average Conditional Exceedance Rate (ACER) method [13, 14] to estimate extreme rainfall in Chiang Mai, Thailand. The maximum monthly rainfall data is collected by the Meteorological Department of Thailand. Understanding extreme rainfall can improve in structural hydraulic design, thereby enhancing hydrological comprehension. Moreover, it can significantly contribute to the development of more effective early warning systems and disaster preparedness strategies.

2. MEASUREMENT LOCATION

This research focuses on analyzing extreme rainfall events in Chiang Mai, Thailand, using data recorded at measurement stations from 1999 to 2022. The study examines the intensity and frequency of these extreme rainfall occurrences over a 23-year period, providing insights into regional weather patterns and their potential impacts. The locations of the measurement stations across Chiang Mai are illustrated in Figure 1, offering a visual context for the study's geographical scope.

Figure 1: The location of the rainfall measurement stations

The data were collected from a network of rainfall gauge stations managed by the Meteorological Department of Thailand, which operates and maintains these stations across various locations in Chiang Mai. These stations are equipped with advanced rainfall measurement instruments designed to capture accurate data on precipitation levels, which are then used to monitor weather patterns and inform decision-making related to flood forecasting, water resource management, and agricultural planning. The types of equipment used at these stations include rain gauges, automated data loggers, and sensors that ensure precise and reliable readings of rainfall events. The specific setup and layout of the equipment used at these stations are illustrated in Figure 2, providing a detailed visual representation of the tools and technologies employed in the data collection process.

Figure 2: Rain gauge equipment (Source: http://www.cmmet.tmd.go.th /instrument /instruments.php)

3. ACER METTHOD

The objective of the extreme value analysis is to provide a prediction of the largest rainfall corresponding to specified probability of exceedance levels (or equivalently return periods). The rainfall observed at each station is then considered to represent an underlying stochastic process. The relevant time interval, for which the rainfall, V , is considered, is taken to be [0, T].

In the present study, prediction of the extreme value of the rainfall is performed by means of the average conditional exceedance rate (ACER) method, which is a numerical approach in order to estimate the extreme values by constructing the corresponding ACER functions [13] of different order, k. It can be applied to analyze time series realizations of a stochastic process for both stationary and non-stationary data sets. The principle and development of extreme value estimation by means of ACER functions is described in more detail by Naess and Gaidai [13] and Naess, Gaidai and Karpa [14]. These functions are applied as a basis for developing the function given in equation 1:

$$P(\eta) \approx \exp\left\{-(N-k+1)\cdot \hat{\varepsilon}_k(\eta)\right\} \tag{1}$$

where $\hat{\varepsilon}_k(\eta)$ is the empirical ACER function of order, k as given in equation 2. Although increasing accuracy is obtained for increasing order k of the ACER function, the number of data points for calculation of $\hat{\varepsilon}_k(\eta)$ is reduced according to the corresponding numerical scheme. Generally, the ACER functions of level η are highly regular in the tail region, assumed to apply for levels beyond a suitably chosen tail marker η_0.

$$\varepsilon_k(\eta) \approx q_k \cdot \exp\left\{-a_k \cdot (\eta - b_k)^{c_k}\right\}, \quad \eta \ge \eta_0 \tag{2}$$

Here a_k, b_k, c_k and q_k are parameter constants, that are dependent upon the order, k. The valid range for the values of the ACER coefficients are $a_k > 0$, $b_k \le \eta_0$ and $c_k > 0$. When the values of a_k , b_k , c_k and q_k are obtained, the extrapolation scheme described by Eq. 2 can be applied to provide reasonably accurate estimation of deep tail extreme values needed for obtaining long return period design values. The optimal values of the parameters are obtained by minimizing the mean square error as expressed in equation 3.

$$F(a_k, b_k, c_k, q_k) = \sum_{i=1}^{M} \rho_j \left| \ln\left(\hat{\varepsilon}_k(\eta_i)\right) - \ln(q) + a\cdot(\eta_i - b)^c \right|^2 \tag{3}$$

where ρ_i is a weight factor to enhance the influence from the most reliable data points. $\eta_i, i = 1,...,M$ are levels of the ACER function, for which data points are available. The data fitting here is based on $\rho_i = \left(\ln CI^+(n_i) - \ln CI^+(n_i)\right)^{-2}$ where CI^+ and CI^- are the bounds of the 95 percent confidence interval, CI. By fixing the values of the b_k and c_k parameters, obtaining optimal values of the a_k and $\ln q_k$ parameters reduces to a standard weighted linear regression problem in terms of ρ_i, $y_i = \ln \hat{\varepsilon}_k(\eta_i)$ and $x_j = (\eta_j - b)^c$. Specifically, the optimal values of a_k and $\ln q_k$ are expressed by equations 4 and 5.

$$a_k^*(b_k, c_k) = -\frac{\sum_{i=1}^{M} \rho_i \cdot (x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sum_{i=1}^{M} \rho_i \cdot (x_i - \bar{x})^2} \tag{4}$$

$$\ln\left(q_k^*(b_k, c_k)\right) = \bar{y} + a_k^*(b_k, c_k) \cdot \bar{x} \tag{5}$$

where $\bar{x} = \sum_{i=1}^{M} \rho_i x_i \Big/ \sum_{i=1}^{M} \rho_i$ and $\bar{y} = \sum_{i=1}^{M} \rho_i y_i \Big/ \sum_{i=1}^{M} \rho_i$

The optimal values of the b_k and c_k parameters are now found by means of the Levenberg-Marquardt method. The final ACER function can be estimated from the fitted curve in order to optimize the confidence interval of the predicted value. The selection of threshold values for prediction of the extreme value is not a very critical issue, however, they should still be chosen with some care. Finally, with the assistance of the efficient extrapolation scheme, which is based on the assumption of regularity of the ACER functions with respect to the deep tail regions, the extreme distribution of rainfall can be obtained

4. Results

Extreme value analysis of rainfall in Chiang Mai is performed in order to estimate the characteristic largest rainfall corresponding to given return periods, which represent the average interval of time within which a certain intensity of rainfall is statistically expected to occur once. This type of analysis is crucial for assessing hydrological risks and is widely used in the design and safety evaluation of hydraulic structures such as dams, spillways, culverts, and drainage systems. Accurately estimating extreme rainfall helps engineers ensure that such infrastructure can withstand severe weather events and prevent failures or flooding. In this study, extreme value analysis is conducted using the Average Conditional Exceedance Rate (ACER) method, which is particularly suited for analyzing rare events with limited data. The ACER method is based on empirical ACER functions that quantify the probability of exceedance conditioned on previous exceedances and are plotted as a function of rainfall magnitude, denoted by the threshold level *k*. These functions provide a robust means of estimating extreme quantiles without assuming a specific probability distribution. The ACER functions for various values of *k* are illustrated in Figure 3, offering a graphical interpretation of the exceedance behavior and helping identify the magnitude of rainfall associated with specific return periods in the Chiang Mai region.

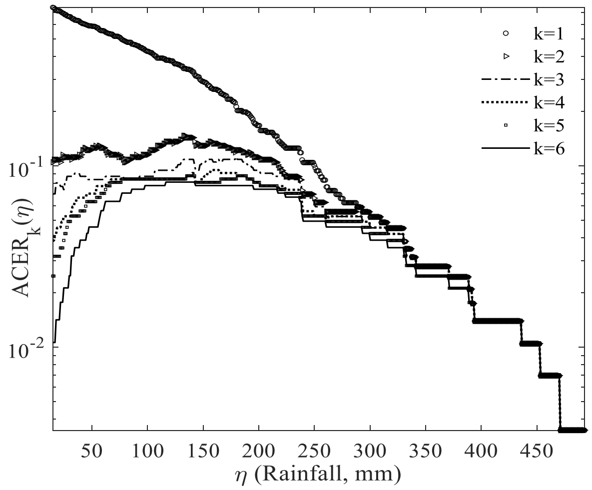

Figure 3. Examples of ACER functions with different orders (k) for rainfall in Chiang Mai.

The results obtained from the ACER method for extreme rainfall estimation indicate that the characteristic maximum rainfall values for Chiang Mai are approximately 770 mm, 822 mm, and 847 mm, corresponding to return periods of 25 years, 50 years, and 100 years, respectively. These values represent the expected maximum rainfall amounts that may occur, on average, once every 25, 50, and 100 years, and are critical parameters for the design and risk assessment of flood control and water management infrastructure. Figures 4 through 6 illustrate the ACER-based estimation processes for each of these return periods, highlighting the stepwise analysis and the behavior of the empirical functions. Moreover, the relationship between extreme rainfall magnitudes and their corresponding return periods is graphically represented in Figure 7. This figure provides a comprehensive overview of the trend in increasing rainfall intensity with longer return periods, offering valuable insight for engineers and policymakers involved in the planning and design of resilient infrastructure to withstand rare but potentially catastrophic rainfall events. The smooth curve fitted through the data points in Figure 7 further supports the reliability and consistency of the ACER method in modeling extreme rainfall phenomena.

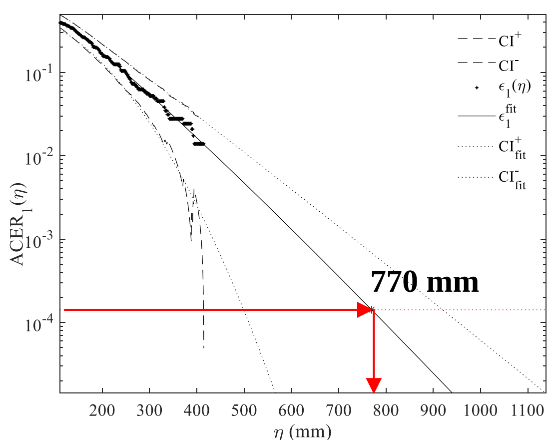

Figure 4. Extreme value prediction for the rainfall based on for a 25 -year return period

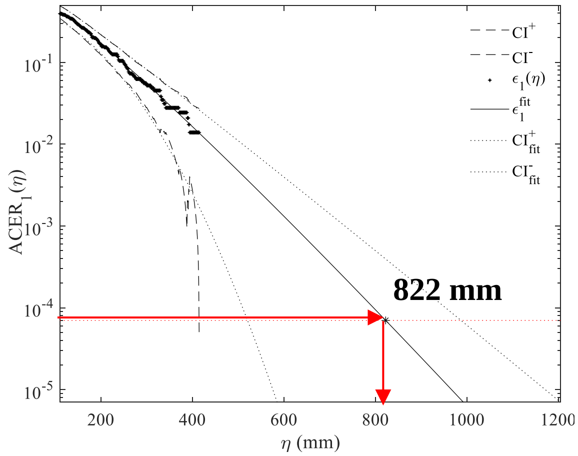

Figure 5. Extreme value prediction for the rainfall based on for a 50 -year return period

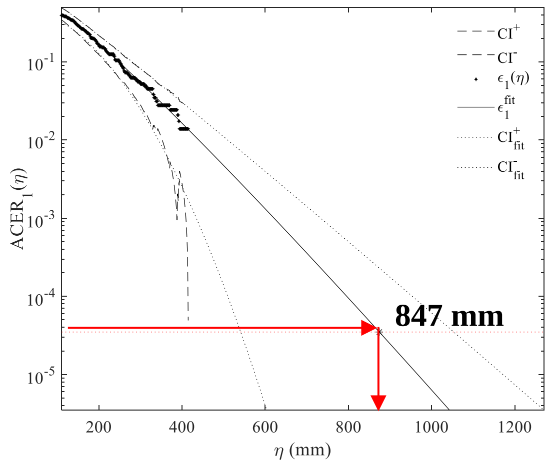

Figure 6. Extreme value prediction for the rainfall based on for a 100 -year return period

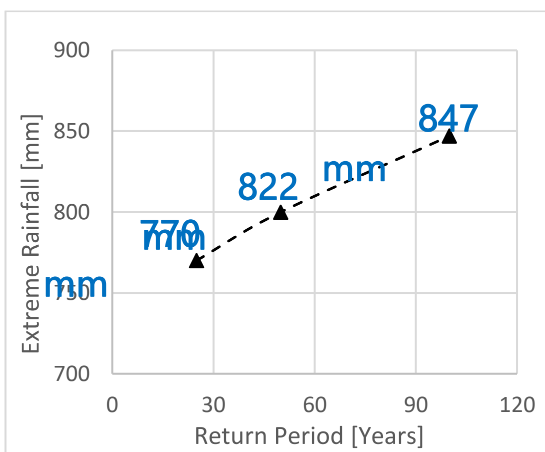

Figure 7. Extreme rainfall versus the return period by using ACER method

In hydraulic engineering, the design of hydraulic structures typically incorporates the flow rate as a crucial design factor, as it directly impacts the performance, stability, and safety of infrastructure such as culverts, spillways, stormwater systems, and flood control channels. However, the amplitude of the flow rate is inherently dependent on the amount of rainfall, making rainfall one of the most influential hydrological inputs in hydraulic calculations. A significant and dynamic relationship exists between rainfall and flow rate, as the former has the capacity to directly influence the volume and velocity of water within natural and engineered waterways. During periods of heavy rainfall, the catchment area receives a substantial influx of water, resulting in increased runoff and a notable surge in the volume of water entering rivers, streams, and drainage systems thereby elevating the flow rate. Conversely, in times of low or absent rainfall, the inflow to these systems diminishes, leading to a corresponding decrease in flow rate. While the flow rate is also affected by other factors such as watershed topography, land use patterns (e.g., urbanization, vegetation cover), soil infiltration capacity, and the efficiency of drainage infrastructure, rainfall remains the principal driver of hydrological response. Understanding the magnitude and frequency of extreme rainfall events is therefore essential for anticipating peak flow rates and designing structures that are resilient under extreme conditions. As such, conducting research on extreme rainfall within the context of hydraulic engineering not only enhances predictive accuracy for flow behavior but also contributes significantly to the development of robust and adaptive water management strategies, particularly in regions vulnerable to climate variability and intense weather events.

5. Conclusion

This study employed a novel and robust method for extreme value estimation, namely the Average Conditional Exceedance Rate (ACER) method, to evaluate and predict extreme rainfall events in Chiang Mai, Thailand. The ACER method, known for its flexibility and reliability in modeling rare events without requiring strict assumptions about the underlying distribution, was successfully applied to long-term rainfall data to derive characteristic extreme rainfall values corresponding to various return periods. The results affirm the suitability and effectiveness of the ACER method, demonstrating its strong potential for application in hydrological and hydraulic studies aimed at understanding and managing weather extremes. The estimated extreme rainfall values obtained from this method can be directly translated into extreme flow rates through hydrological modeling processes, enabling the accurate determination of design discharges that are essential for the planning and construction of hydraulic structures such as dams, levees, drainage channels, and flood protection systems. By providing reliable estimates of rare but high-impact rainfall events, this approach significantly enhances the capacity of engineers and planners to develop infrastructure that is both safe and resilient under extreme hydrometeorological conditions. Furthermore, the investigation of extreme rainfall through advanced statistical methods such as ACER contributes valuable insights into risk assessment and climate adaptation strategies, making it an important asset in the field of hydraulic engineering and sustainable water resource management.

Acknowledgements

This research was partially supported by Chiang Mai University, with additional thanks to the support of the City Research and Development Center, Frontier Research in Urban Intelligence, Faculty of Engineering, Chiang Mai University, Thailand.

This research work was also partially supported by the Faculty of Engineering, Chiang Mai University. Furthermore, this work is supported by the CMU Junior Research Fellowship Program.

References

[1] Miniussi, A., and Marani, M., 2020, "Estimation of daily rainfall extremes through the metastatistical extreme value distribution: Uncertainty minimization and implications for trend detection," Water Resources Research, 56(7), p. e2019WR026535.

[2] Bruce, J. P., 1994, "Natural disaster reduction and global change," pp. 1831-1835.

[3] Obasi, G. O. P., 1994, "WMO's role in the international decade for natural disaster reduction," pp. 1655-1661.

[4] Katz, R. W., and Brown, B. G., 1992, "Extreme events in a changing climate: Variability is more important than averages," pp. 289-302.

[5] Groisman, P. Y., 1999, "Changes in the probability of heavy precipitation: Important indicators of climatic change," pp. 243-283.

[6] Data, C., 2009, "Guidelines on analysis of extremes in a changing climate in support of informed decisions for adaptation," World Meteorological Organization.

[7] Katz, R. W., Parlange, M. B., and Naveau, P., 2002, "Statistics of extremes in hydrology," Advances in Water Resources, 25(8), pp. 1287-1304.
[8] Papalexiou, S. M., and Koutsoyiannis, D., 2013, "Battle of extreme value distributions: A global survey on extreme daily rainfall," Water Resources Research, 49(1), pp. 187-201.
[9] Papalexiou, S., Koutsoyiannis, D., and Makropoulos, C., 2013, "How extreme is extreme? An assessment of daily rainfall distribution tails," Hydrology and Earth System Sciences, 17(2), pp. 851-862.
[10] Torsri, K., Faikrua, A., Peangta, P., Sawangwattanaphaibun, R., Akaranee, J., and Sarinnapakorn, K., 2023, "Simulating Heavy Rainfall Associated with Tropical Cyclones and Atmospheric Disturbances in Thailand Using the Coupled WRF-ROMS Model—Sensitivity Analysis of Microphysics and Cumulus Parameterization Schemes," Atmosphere, 14(10), p. 1574.
[11] Khamkong, M., Bookkamana, P., Shin, Y., and Park, J.-S., 2017, "Modelling extreme rainfall in northern Thailand with estimated missing values," Chiang Mai Journal of Sciences, 44(4), pp. 1792-1804.
[12] Komori, D., Nakamura, S., Kiguchi, M., Nishijima, A., Yamazaki, D., Suzuki, S., Kawasaki, A., Oki, K., and Oki, T., 2012, "Characteristics of the 2011 Chao Phraya River flood in Central Thailand," Hydrological Research Letters, 6, pp. 41-46.
[13] Naess, A., and Gaidai, O., 2009, "Estimation of extreme values from sampled time series," Struct Saf, 31(4), pp. 325-334.
[14] Naess, A., Gaidai, O., and Karpa, O., 2013, "Estimation of extreme values by the average conditional exceedance rate method," Journal of Probability and Statistics, 2013.