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EARTHQUAKE FORECASTING IN BANGLADESH AND ITS SURROUNDING REGIONS

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Abstract

Earthquake is one of the most dreadful natural disasters which have caused incalculable destruction of properties and human lives. An examination of the historical catalog of Bangladesh and its surrounding regions reveal that several earthquakes of large magnitude with epicenters within this region have occurred in the past. In this paper, we have analyzed the previous earthquake data up to 2008 of Bangladesh and its adjacent regions with spatial distribution and have tried to find out the probable earthquake risk with magnitude ($m_s \geq 6.0$) in this region. Our goal is to forecast waiting times until the next earthquake in Bangladesh and its surrounding regions for a magnitude of earthquake ($m_s \geq 6.0$). For the prediction of the next strong earthquake, we have used Weibull distribution which is the best way to carry out probabilistic hazard analysis of earthquake occurrences and compared this distribution with the log-normal distribution and exponential distribution for the occurrence of earthquake in Bangladesh and its surrounding regions.

Keywords: Bangladesh, Earthquake, Probability, Weibull Distribution, Log-normal Distribution, Exponential Distribution.

Introduction

Bangladesh, which is located between 20.35° N to 26.75°N Latitude and 88.03° E to 92.75° E Longitude, one of the most disaster prone countries in the world. Due to its geographic location and population density, it experiences different types of natural disasters which cause losses to lives and properties every year. Lying in the confluence of India–Burma-Eurasia plate, it is extremely prone to earthquake. Geologically, Bangladesh is located in such a position where five major faults are involved and some main rivers (like Tista-Lalmonirhat, Brahmaputra-Kurigram, Surma-Sylhet) are entered into this country. The boundary of Northern part, Western part and North-East part of Bangladesh are directly joined with the most earthquake prone regions (Calcutta, Assam, Tripura) of India. According to the geological location five major faults i.e., (i) Bogra fault zone (ii) Tripura fault zone (iii) Sub-Dauki fault zone (iv) Shillong plateau and (v) Assam plateau are active in Bangladesh(Hossain A., 1998; Shongkour Roy, 2014). For the presence of these major faults, Bangladesh is facing dreadful threat. Earthquake occurs in the world every moment, all of these are not felt which are very minor ($m_s \leq 3.0$) and are not vulnerable for us but strong earthquakes ($m_s \geq 6.0$) cause terrible situation.

A few years ago, the earthquake of Bangladesh has been studied (B. K. Chakravorti, 2010). Recently, the probabilistic prediction for the earthquake of Bangladesh has been also studied on March 2014 (Shongkour Roy, 2014). But in this paper we have fore-casted the statistical probability for the earthquake of Bangladesh using the Weibull distribution, Log-normal distribution and Exponential distribution. The statistical probability forecasting of these distributions have been compared between them so that we can forecast the probability to occur the earthquake in future in Bangladesh more accurately.

Earthquake in Bangladesh in the Past

Information on earthquakes in and around Bangladesh is available for the last 250 years. The earthquake record suggests that since 1900 more than 100 moderate to large earthquakes occurred in Bangladesh, out of which more than 65 events occurred after 1960. This brings to light an increased frequency of earthquakes in the last 30 years. This increase in earthquake activity is an indication of fresh tectonic activity or propagation of fractures from the adjacent seismic zones. Before the coming of the Europeans, there was no definite record of earthquakes in this region. From the previous earthquake records, it is obviously known that these boundaries are the most dangerous zone for occurring earthquake. The great and major earthquakes that affected Bangladesh seriously damaged, most of these epicenters were located in the boundary between Bangladesh and India by which region most of the rivers entered into Bangladesh.

Table-1: Frequency of occurrence of earthquakes (United States Geological Survey, 1918-2008)

Descriptor	Magnitude	Average Annually
Great	8 and higher	1
Major	7 - 7.9	17
Strong	6 - 6.9	134
Moderate	5 - 5.9	1319
Light	4 - 4.9	13,000 (estimated)
Minor	3 - 3.9	130,000 (estimated)
Very Minor	2 - 2.9	1,300,000 (estimated)

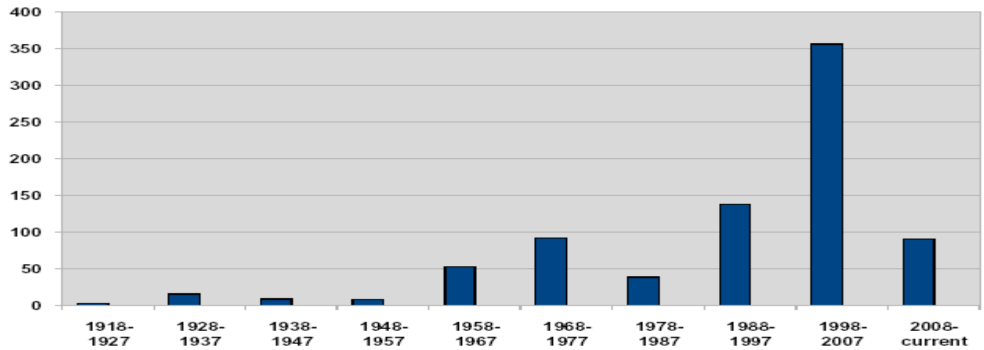

Figure-1: Number of occurrence of earthquake versus year (Geological Institute, Quetta, Pakistan)

The number of occurring earthquakes in Bangladesh and its surrounding area are really large. Earthquakes having lower magnitudes ($m_s \leq 5.0$) are larger in numbers but bear less threat for us. There are few numbers of earthquakes having higher magnitudes ($m_s \geq 7.0$) but they are very destructive for any country. Bangladesh faced a large numbers of earthquakes in past and still continued. Most of the earthquakes occurred in the adjacent countries and affected Bangladesh shown in the Table-2 (Mehedi Ahmed Ansary and Md. Rezaul Islam, 2008).

Table-2: Earthquake epicenter location with respect to Bangladesh

Name of earthquake	Fault name	Time of occurrence	Magnitu-de	Distance from Sylhet (in km)	Distancc from Dhaka (in km)	Distance from Rajshahi (in km)
Cachar earthquake	Tripura	1869	7.5	92	250	------
Bengal earthquake	Bogra	1885	7.0	234	170	100
Great Indian earthquake	Assam	1897	8.7	151	230	310
Srimangal earthquake	Sub-Dauki	1918	7.0	71	150	222
Dhubri earthquake	Bogra	1930	7.1	195	250	250

Statistical Probability Distribution

There are different types of methods for earthquake prediction, statistical method is one of them. Here we have used the statistical method for forecasting the earthquake in Bangladesh and its surroundings. For this purpose we choose the Weibull distribution. We have also chosen another two distributions those are Log-normal distribution and Exponential distribution to compare with Weibull distribution. The Weibull distribution has also been widely used for specifying the distribution of earthquake recurrence times (Rikitake, 1982). The PDF for a Weibull distribution of recurrence times is given by (Patel et al., 1976)

$$P(t) = \frac{\beta}{\tau}\left(\frac{t}{\tau}\right)^{\beta-1} \exp\left[-\left(\frac{t}{\tau}\right)^{\beta}\right] \quad \ldots\ldots(1)$$

Where β and τ are fitting parameters. The CDF for a Weibull distribution is given by

$$P(t) = 1 - \exp\left[-\left(\frac{t}{\tau}\right)^{\beta}\right] \quad \ldots\ldots(2)$$

We consider the hazard function $h(t_0)$. This is the probability that an earthquake will occur at the time t_0 if it has not previously occurred and is given by

$$h(t_0) = \frac{P(t_0)}{1 - P(t_0)} \quad \ldots\ldots(3)$$

Where Δt is waiting times for an earthquake on a fault if the time since the last earthquake is t_0. The waiting time is measured forward from the present, thus $t = t_0 + \Delta t$.

From equation (1), (2) and (3) the hazard function for the Weibull distribution is,

$$h(t_0) = \frac{\beta}{\tau}\left(\frac{t_0}{\tau}\right)^{(\beta-1)} \quad \text{…………………………………………….(4)}$$

(Gleb Yakovlev, Donald L. Turcotte, John B. Rundle, and Paul B. Rundle, 2006) the log-normal is one of the most widely used statistical distributions in a wide variety of fields. The PDF for a log-normal distribution of recurrence times t is given by (Patel et al., 1976)

$$P(t) = \frac{1}{(2\pi)^{1/2}\sigma_y t}\exp\left[-\frac{(\ln t - \bar{y})^2}{2\sigma_y^2}\right] \quad \text{……………………….(5)}$$

Where $y = \ln t$; $\bar{y}$ and σ_y are the mean and standard deviation of this equivalent normal distribution. And the CDF of the log-normal distribution is given by (Gleb Yakovlev et al., 2006)

$$P(t) = \frac{1}{2}\left[1 + erf\left(\frac{\ln t - \bar{y}}{\sqrt{2}\sigma_y}\right)\right] \quad \text{……………………………….(6)}$$

And the exponential distribution can be written with the rate of λ is

$$P(t) = \lambda e^{-\lambda t} \quad \text{……………………………….(7)}$$

Where the waiting time is measured forward from the present, thus $t = t_0 + \Delta t$, Δt is waiting times for an earthquake on a fault if the time since the last earthquake is t_0.

Data Analysis

For our statistical analysis we have considered thirty one earthquakes that occurred from 1918 to 2008.Here we have considered the earthquakes with the magnitude level 6 and above. These earthquakes are strong enough to damage infrastructures and to cause the loss of lives for human and animals. The year in which earthquakes occur are as 1918, 1923,1927, 1930, 1932, 1933, 1934, 1935, 1936, 1938, 1940, 1941, 1943, 1954, 1955, 1956, 1957, 1958, 1959, 1964, 1970, 1975, 1980, 1993, 1994, 1995, 1997, 2000, 2004, 2007 and 2008. Average time interval between two successive earthquakes has been counted and the average value 3.0 years were found using these data. Values of fitting parameters for Weibull distribution and the rate of the exponential distribution also calculated from these data.The values of fitting parameters β, τ and the rate of exponential distribution λ are 1.205, 3.22 and 0.333 respectively.

Result and Discussion

Data show that the average time of an earthquake having magnitude equal to or more than 6 in Bangladesh and its surroundings region is 3.0 years.

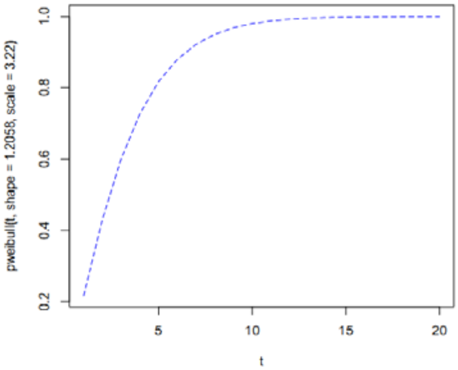

Figure-2: The graph of CDF of the Weibull distribution.

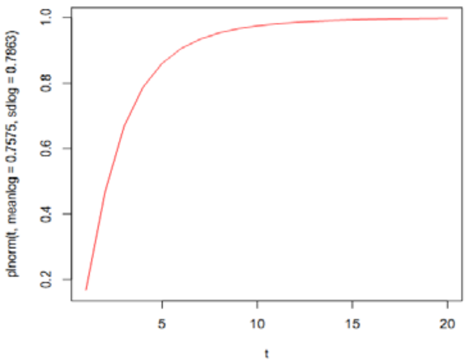

Figure-3: The graph of CDF of log-normal distribution

Figure-2 shows the graph of CDF of Weibull distribution function. This figure provides the probability of an earthquake having a magnitude of equal to 6 or more in Bangladesh and its surroundings the probability of occurrence an earthquake in this region in t years later.

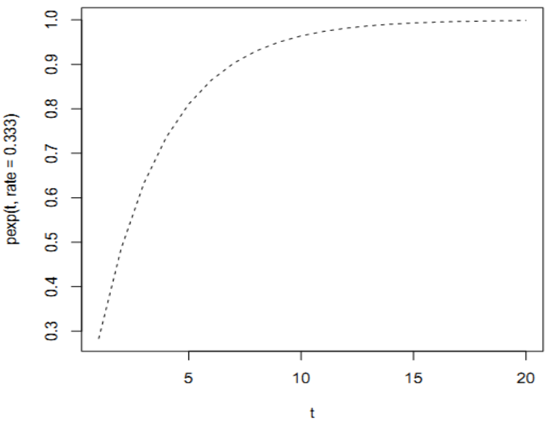

Figure-4: The graph of exponential distribution

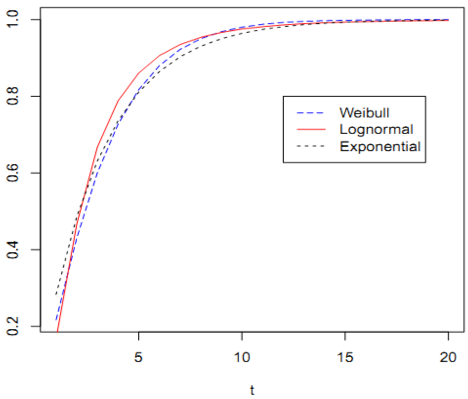

Figure-5: The graph of comparison between CDF Weibull distribution, CDF log-normal distribution and exponential distribution

Similarly for the same magnitude of an earthquake in this area will occur after t years the probability also represented in the figure-3 and figure-4 using equation (6) and (7). Figure-3 shows the CDF log-normal distribution and figure-4 shows the exponential distribution function probability. And the figure-5 gives comparison between CDF Weibull distribution probability, CDF log-normal distribution and the exponential distribution.

Conclusion

The above discussion of the three distributions tell us the probability of an strong earthquake having magnitude $m_s \geq 6.0$ after 7 years from 2008 (2015) in this region is 92%, 93% and 90% for Weibull distribution, log-normal distribution and exponential distribution respectively. But in coming years the probability of an earthquake occurrence increases for all distributions and after 20 years from 2008 (2028) it becomes 99.8%. This indicates that the coming years are highly risky years for the region of the five major faults (Bogra fault zone, Tripura fault zone, Sub-Dauki fault zone, Shillong plateau and Assam plateau).

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