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Appraisal of Main Extreme Parameters of Earthquakes in Nigeria Using the Weibull Equations

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Authors' contributions

This work was carried out in collaboration among all authors. Author AAA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BUA and CAU managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study investigated earthquake occurrences in Nigeria using the Weibull equations. The data employed in this study was the historical and instrumental data recorded from 1933 to 2018. The relationship between intensity scale and Richter magnitude scale given by Gutenberg and Richter was used to convert from intensity scale to Richter scale. The Weibull equations were used to compute probabilities and return periods of earthquakes. The findings of the study revealed that the return period for an earthquake of magnitude 6.5 on Richter's scale is 86 years; an earthquake of magnitude 4.7 is 34.4 years; an earthquake of magnitude 4.2 is 17.2 years and earthquake of magnitudes 2-3.7 is between 5.56-14.3years. This implies that Nigeria may not likely experience any earthquake of magnitude 6.5 till the year 2025 since earthquake of magnitude 6.5 last occurred in 1939 but the probability of occurrence is 1.16% or 0.0116. Earthquakes of highest magnitudes 6.5, 4.7 and 4.2 on Richter's scale for a 100 year period which indicate the most hazardous in the location with probabilities exceedance of 1.16%, 2.91% and 4.65% were evaluated. It was observed that as the time increases the probability of occurrence of these earthquakes increases with it and vice versa with magnitude 4.2 having (99.1%), magnitude 4.7 having (94.8%) and magnitude 6.5 having (80.07%). But earthquake forecast or prediction is still a

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complicated issue due to saturation of earthquake magnitudes and variation in seismic data collection by different seismic stations and networks. The implication of this study is that the findings will help Nigeria government to protect its people, infrastructures and the constructions that are going to take place especially earthquake – prone areas like southwestern Nigeria.

Keywords: Earthquakes; Weibull equations; main extreme parameters; intensity scale; Nigeria.

1. INTRODUCTION

Earthquake is one of the global natural disasters facing man. With the advancement in technology, man still finds it difficult to predict earthquake motion with proper understanding of seismic source and properties of seismic waves.

Nigeria is situated in the intraplate region of the African plate that consists of all Africa and the eastern half of the Atlantic. Because of this one does not expect earthquakes to occur in this country. Nigeria has experienced various minor earthquakes in different parts of the country. The first occurrence of earth tremor in Nigeria was in 1933. Other events were reported in 1939, 1964, 1984, 1985 (in KombaYaya), and 1987 (in Akko) near Gombe, 1990, 1994, 1997, 2000 and 2006 [1]. Following the tremor that occurred on September 11, 2009 which had impact on western parts of Nigeria, Oyo, Bayelsa, Rivers and Kaduna States have experienced earth tremors in 2016 [2].

The history of earthquake in Nigeria started in the early 1930s when tremors were experienced in some areas of Warri in 1933 and Ibadan on 22nd June 1959. It was reported that the 1939 earth tremor was felt in parts of Ile Ife and Lagos was likely linked to the Accra earthquake that occurred on that day.

Majority of these earth tremor occurrences were not instrumentally recorded due to non-functional seismological observatories in Nigeria but those of 1984 at Ijebu-Ode, 1990 at Ibadan and 2000 at Jushi Kwari were recorded. According to [2], earth tremors with different magnitudes and intensities have been recorded in Nigeria over the past 80 years. The epicenters of most of these events were predominantly situated in the southwestern Nigeria. No report of loss of lives or pronounced damages to property until 2016.

With the recent occurrence of earth tremors it is a sign that Nigeria is not seismically free as people believed. It is against this backdrop that this study is carried out to appraise main extreme parameters of earthquakes in Nigeria using Weibull equations.

1.1 Location / Geology of Nigeria

Nigeria is situated on latitudes 4^0N and 14^0N and longitudes 3^0E and 14^0E in the Pan African mobile belt. It is sandwiched between the West Africa and Congo cratons. Nigeria has a landmass of 923,768.km^2 and share boundary with the Republics of Niger and Chad in the north and Republic of Benin in the West (Fig. 1). The eastern side shares boundary with the Republic of Cameroon up to the shores of the Atlantic Ocean.

1.2 Geologic and Tectonic Setting of Nigeria

According to [5], the geology of Nigeria consists of mainly Crystalline and sedimentary existing almost in the same measures. The Crystalline rock consists of rock comprises the Precambrian Basement Complex and the Phanerozoic rocks which are dominant in the east and north central area of the country region of the country. The Precambrian Basement rocks consist of the gneissic, migmatite, quartzite complex. The Basement Complex constitutes about 50% of the Nigerian geology.

The Nigerian geologic environment is made up of seven major sedimentary Basins which include: the Calabar Flank, the Benue Trough, the Chad Basin, Sokoto Basin, the Dahomey Basin, Niger Delta and the Anambra Basin (Fig. 2). The Pan African Orogeny which took place around about 600 ± 100Ma was the final transformation and change of rocks experienced in the belt with a little side effect on the neighbouring craton.

1.3 Description of Nigeria Earthquakes

The history of earthquake in Nigeria according to [6] started in the early 1930s when tremors were experienced in some areas of Warri in 1933 and Ibadan on 22nd June 1959. [7] reported that the 1939 earth tremor was felt in parts of Ile Ife and Lagos was likely linked to the Accra earthquake that occurred on that day.

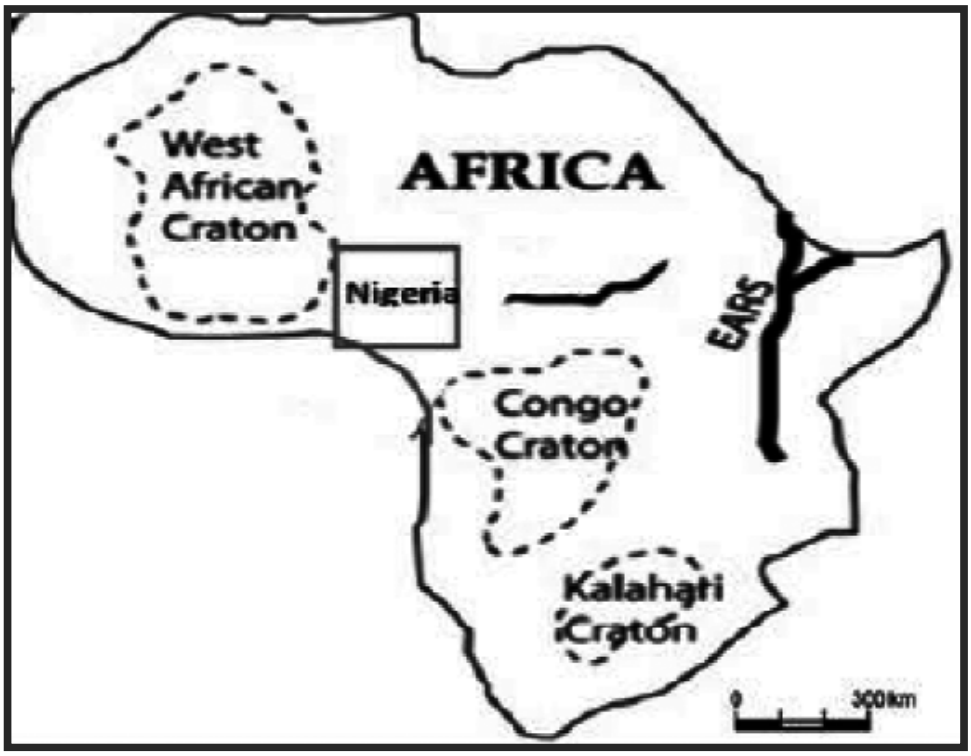

Fig. 1. Location of Nigeria [3] and [4]

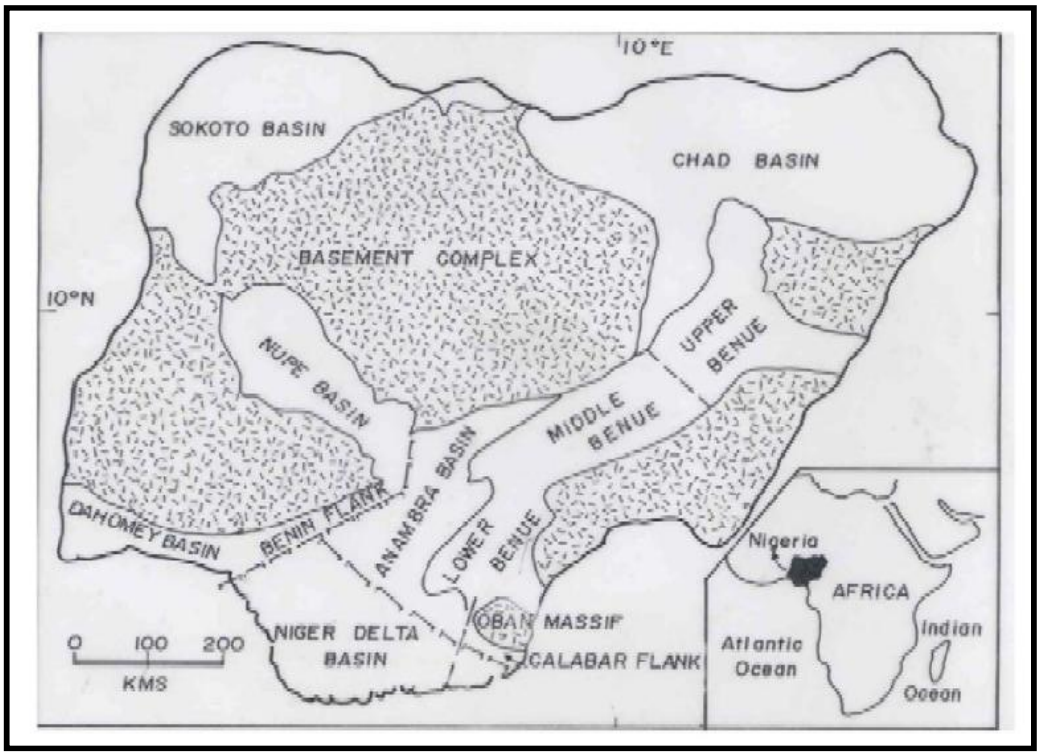

Fig. 2. Geological Map of Nigeria Showing the Distribution of the Sedimentary Basins and the Basement Complex [4]

The July 28, 1984 earthquake event that occurred in Ibadan, Ijebu – Ode, Shagamu and Abeokuta southwestern Nigeria attracted the attention and concern of seismologists and the public. According to [7], the reason is because these regions are situated in the Basement Complex which seismologists and scientists considered to be seismically stable than other regions.

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[8] and [9] reported that aftershock of earth tremor of July 28, 1984 and August 2, 1984 was experienced at Ijebu-Ode, Ijebu – Remo and Shagamu with a loud noise. Buildings shook, hanging objects vibrated and some fell to the ground and the tremor had an epicentral intensity of V [8].

Also between 18th June and 19th 1985, another event occurred at Kombani Yaya, a village settlement in northern part of Nigeria [10] and [11]. The vibration that accompanied this tremor had an intensity of V on the modified Mercalli scale and two surface fractures were observed. The tremor was extremely experienced by many people in these areas, buildings and trees were shaken, items on shelves fell to the ground.

Nigeria is believed to be aseismic and not known to lie on any seismic belt [12]. Despite the fact that it lies far from the world's active plate boundaries and rests on stable continental crust, [13] reported that it has experienced several tremors. Seismic events have been recorded in Nigeria since 1933 [14] and a total of 15 tremors have been measured to date as revealed by [12], although [3] reported about 31 incidences with about four coming from adjoining countries of Ghana and Cameroun. The tremors are distributed among the Basement Complex and the sedimentary basins.

Since 1933 when the first tremor occurred in the country, over thirty nine (39) events have been revealed. Of these 39 tremors, less than 20% were instrumentally recorded. The tremors experience in more than one geographical location at a time is estimated to be over forty-eight (48) instances and felt in many communities cutting across about twenty-two (22) states of the federation with the Federal Capital City, Abuja making percentage coverage of about 60%. About 52% of the events occurred in the South-Western parts of the country with Ogun and Oyo states been the most affected occurring majorly within the Ijebu-Ode and Ibadan axis. This axis lies along the Ifewara-Zungeru lineament [4].

Another notable event that has attracted the concern of scientists happened on Wednesday, June 27, 1990 and was experienced around Ibadan and its environs [6],[9] and [15]. This was measured by the seismic station of Geological Survey of Nigeria in Ilorin with a local magnitude of 3.7. Although the epicentre was not given, it could be inferred that it was close to that of Ijebu-Ode event.

The Centre of Geodesy and Geodynamics, Toro in Bauchi State, reported that the average value of intensities for Nigerian Earthquakes ranges from III –VI on the Modified Mercalli Scale. The M_L is averaged at 3.7 – 4.2 Mp is averaged at 4.3 - 4.5 and M_S is averaged at 3.7 – 3.9.

1.4 Probable Causes of Earth Tremors in Nigeria

The source of earth tremors in Nigeria are as a result of many factors. According to [12] and [3], stresses that develop in the vicinity of plate boundaries could move towards the centre of the plates inducing intraplate tremors normally in pre-existing faults.

[14] and [12] reported that earthquake distribution is due to regional stress and weak zone in the crust or transfer of stress from plate boundaries. The condition of inhomogeneities and regions of weakness are as a result of original episodes of magmatic intrusion may be responsible for earth tremor creation.

Researchers like [16], [17] and [18] revealed that the likely mechanism of the causes of earth tremors in Nigeria could be associated with the Oceanic (Romanche and Chain) fracture zones. These fractures zones which are dominant in the Western part of Nigeria according to [7], [19], [20] and [1] are responsible for the seismic activities experienced in the areas.

The important fault systems in Nigeria as reported by [3] is the Ifewara- Zungeru, the Yola-Dambata; Akka-Jushi, and Warri-Ijebu Remo fault systems. The Ifewara zungeru fault is believed to be restricted to the Atlantic fracture system, the Romanche fault system [14] and is the longest linear feature within the Precambrian Basement Complex of Nigeria. It is a 250 km trending NE - SW mega structure [21]. It stretches from East of Ijebu Ode in the South through Ifewara, Iwaraja, Okumesito the Basin of

River Niger, South of Lafiagi to Zungeru and beyond to Kalangai in North – Western Nigeria [18]. [7] reported that the many NW - SE trending faults along the Ijebu – Ode - Ibadan – Oyo Axis could be where the earthquakes could have originated and is linked to the Mid- Atlantic transform fracture zones in the Gulf of Guinea.

The Abakiliki and Benue Troughs are regarded as failed rift arms due to the opening of the South Atlantic. According to [22], 49% of all the intraplate earthquakes happen close to ancient failed rifts or passive margins and this could also be one of the likely causes of earth tremors in Nigeria. Also [23] reported that the troughs consist of folded and unfolded prominently Cretaceous sediments formed in two late Mesozoic rift troughs constituted the third arm of the Niger Delta Triple Junction. Extensional stress due to upwelling of magma below the area caused deformation in the fault and when the extension stopped, the vulnerable crust was enveloped with sediments over millions of years. According to [12], these regions combined with mid-plate structure and acted upon by tectonic compressive forces.

While most earthquakes are caused by movements of the earth's tectonic plates, human activity can also cause earthquakes. Evidence has found that oil and gas exploration could trigger earthquake and Nigeria is among top oil producing countries. Oil and gas drilling create massive amounts of toxic wastewater. Fluid injection of this water increases the fluid pressure within the fault zones and making them more likely to induce earthquake. When injected with fluids, even faults that have not moved in historical times can be made to slip and cause earthquake if conditions underground are suitable.

The likelihood of group of boreholes causing earthquake has generated a lot of arguments among scientists. Some argued that if the distance between one borehole and another is less than 50 metres it could lead to liquid fire beneath the earth and spark off geological disturbance [4]. Other man's activities that may cause this occurrence are coal mining, oil drilling and storage of huge quantity of water behind a dam etc.

1.5 Literature Review

[24] investigated probabilistic seismic hazard analysis of Nigeria and the limit to probable future earthquake magnitudes in Nigeria. The Gutenberg-Richter recurrence law was employed in the study. Their findings revealed that Nigeria is at the risk of experiencing earthquake magnitudes as high 6.0 in the year 2020; 6.5 between the year 2021 and 2022; 7.0 between the year 2025 and 2026 and 7.1 in the year 2028 with a 36.79% probability.

Also probability that an earthquake of magnitude 7.1 will be experienced from 2019 to 2028 also ranges from 9% to 36.79%.

[25] analyzed earthquakes for years 1913-2016 using Weibull equations to predict future conditions of annual frequency, the return period, the percentage probability for each event, and the probability of a certain magnitude earthquake occurring in West Coast of the Kingdom of Saudi Arabia (Red Sea). The findings of the study found that earthquakes with magnitude 3 or less on Richter's scale has high probability of occurrence while that of maximum magnitude of 6.1 has a return period of 100 years with low probability of about 0.96%.

[26] analyzed the seismic data from the viewpoint of science of complexity, where one of the major aims of seismology is to predict when and where the next main shock will occur after an initial main shock. The rate of return period of earthquakes on a seismic source can be evaluated using the Gutenberg-Richter relationship [27]. [28] studied the return periods of earthquakes. [29] also investigated the statistical models for earthquake occurrences.

[30] applied gamma, log-normal, Weibull and exponential distributions to describe the probability distribution of inter-occurrence time of large earthquakes in Japan. [31] employed Poisson distribution to explain the recurrence times, and estimated the expected value and variance computed for the loss of life and damaged buildings after the change point using the compound Poisson process.

[32] evaluated the seismicity and earthquake hazard parameters of Turkey based on maximum regional magnitude. [33] estimated the mean return periods, the most probable magnitude in a time period of t-years, and the probability of earthquake occurrence for a given magnitude during a time span of t-years for different regions in and around Turkey. They also showed that in the specific region, the most probable earthquake magnitude in the next 100 years would be over 7.5 [34].

2. MATERIALS AND METHODS

2.1 Data Source

The data employed in this study was the historical and instrumental data recorded from 1933 to 2018 (Table 1).

2.2 Methods

The relationship between intensity scale and Richter magnitude scale is given by [27] as:

$$M_L = (2/3)I_0 + 1 \quad (1)$$

or

$$M_L = 0.667\ I_0 + 1 \quad (2)$$

Where M_L is the Richter magnitude scale and I_0 is the intensity scale.

2.3 Weibull Equation

The Weibull equation is very useful in estimating the yearly frequency, the return period or recurrence interval, the percentage probability for each event, and the yearly exceedance probability. The probability of a given-magnitude earthquake occurring in the region during any period can be also calculated. Historic records of earthquakes in Nigeria can be used to predict future conditions about the yearly frequency, the return period, the percentage probability for each event, and the probability of a given-magnitude earthquake happening in the region during any period.

Earthquake prediction is categorized into two. First is the statistical prediction which is based on past events; Data are collected from the records. Second is deterministic prediction which is made from the earthquake signs.

2.4 Extreme Earthquake Evaluation

Most extreme event analysis is concerned with the distribution of annual maximum or minimum values at a given site. These events are given a rank, m, starting with m = 1 for the highest value, m = 2 for the next highest and so on in descending order. The smallest earthquake magnitude will receive a rank equal to the number of total records over the years which there are a record, n. The Weibull formula was employed because of it is easy to use and has been used by many researchers including United States Geological Survey (USGS).

According to the Weibull equation, the return period or recurrence interval T (in years) is calculated using the following equation [35] and [36]:

$$\text{T (years)} = \frac{(n+1)}{m} \quad (3)$$

Where: m = event ranking (in a descending order), and
n = number of events in the period of record.

The percentage probability (annual exceedence probability) for each magnitude in any year is calculated using the reciprocal of the Weibull equation as:

$$\text{P (per cent)} = \frac{100m}{(n+1)} \quad (4)$$

From equation (3),

$$n + 1 = Tm \quad (5)$$

Substituting equation (5) in equation (4)

$$P = \frac{100}{T}\% \quad (6)$$

For example, an earthquake equal to 10-year would have yearly exceedance probability of 1/10 = 0.1 or 10%. This implies that in any given year, the probability that an earthquake with a magnitude equal to or greater than that of a 10 year earthquake would be 0.1 or 10%. In the same way, the probability of an earthquake with a magnitude exceeding the 50 year in any given year would be 1/50 = 0.02, or 2%. Note that such probabilities are the same for every year, but in practice, such an earthquake could occur next year, or be exceeded several times in the next 50 years.

Table 1. Inventory of Historical/Instrumental Earthquakes in Nigeria

S/N	Year-Month-Day	Origin Time	Felt Area	Intensity/ Magnitude	Probable epicenter	Coordinates	
1	1933	-	Warri Ohafia	-	-	$05^0$45'23''E	$05^0$31'42''N
2	1939-06-22	19:19:26	Lagos,Ibadan, Ile Ife	6.5(M_L)	Akwapin fault in Ghana	$03^0$23'00''E	$06^0$30'11''N
3	1948-07-28	-	Ibadan	-	Close to Ibadan	-	-
4	1961-07-02	15:12	Ohafia	-	Close to Ijebu-Ode	-	-
5	1963-12-21	18:30	Ijebu Ode	V	Close to Ijebu Ode	-	-
6	1981-04-23	12:00	Kundunu	III	At Kundunu village	-	-
7	1982-10-16	-	Jalingo,Gembu	III	Close to Cameroun volcanic line	-	-
8	1984-07-28	12:10	Ijebu Ode, Ibadan, Shagamu, Abeokuta	VI	Close to Ijebu Ode	-	-
9	1984-07-12	-	Ijebu Remo	IV	Close to Ijebu Ode	$03^0$23'00''E	$07^0$11'45''N
10	1984-08-02	10:20	Ijebu Ode, Ibadan, Shagamu, Abeokuta	V	Close to Ijebu Ode	-	-
11	1984-12-08	-	Yola	III	Close to Cameroun volcanic line	-	-
12	1985-06-18	21:00	KombaniYaya	IV	KombaniYola	-	-
13	1986-07-15	10:45	Obi	III	Close to Obi Town	$08^0$46'E	$08^0$22'N
14	1987-01-27	-	Gembu	V	Close to Cameroun volcanic line	$11^0$15'E	$06^0$42'N
15	1987-03-19	-	Akko	IV	Close to Akko	$10^0$57'E	$10^0$17'N
16	1987-05-14	-	Kurba	III	Close to Kurba village	$10^0$12'E	$11^0$29'N
17	1988-06-27	12:17	Lagos	V	Close to Lagos	-	-
18	1990-06-27	-	Ibadan	3.7(M_L)	Close to Ijebu Ode	$03^0$58'E	$17^0$22'N
19	1990-04-05	-	Jerre	V	Close to Jerre	-	-
20	1994-11-07	05:07:51	Ijebu Ode	4.7(M_L)	Dan Gulbi	-	-
21	1997	-	Okitipupa	IV	Close to Okitipupa Ridge	-	-
22	2000-08-15	-	Jushi-kwari	III	Close to JushiKwari village	-	-
23	2000-03-13	-	Benin	IV	Benin City (55km from Benin)	-	-
24	2000-03-07	15:53:54	Ibadan,Akure, Abeokuta, Ijebu Ode, Oyo	4.7(M_L)	Close to Okitipupa	-	-
25	2000-05-07	11:00	Akure	IV	Close to Okitipupa Ridge	-	-
26	2001-05-19	-	Lagos	IV	Close to Lagos City	-	-
27	2002-08-08	-	Lagos	IV	Lagos City	-	-
28	2005-03	-	Yola	III	Close to Cameroun volcanic Ridge	-	-

29	2006-03-25	11:20	Lupma	III	Close to Ifewara	-	-
30	2009-09-11	-	Abomey-Calavi	III	Close to Benin	-	-
31	2011-11-05	-	Abeokuta	4.4M	Close to Abeokuta	-	-
32	2016-07-10	-	Saki	IV	Oyo State	-	-
33	2016-08-10	-	Igbogene	III	Bayelsa	-	-
34	2016-09-11	-	Kwoi	III	Kaduna State	-	-
35	2016-09-12	-	Sambaing Dagi	III	Kaduna State	-	-
36	2018-09-05 to 08	-	Mpape	II-IV	Abuja	-	-

(Source: [1], [12], [4] and [24])

2.5 Probability during a Time Period

The probability of a certain-magnitude of earthquake happening during any given period t can be obtained with aid of an equation [37] and [38].

$$P_t = 1 - (1 - P)^t \quad (7)$$

Where P_t is the probability of occurrence over the entire time period, t and P is the probability of occurrence in any year.

2.6 Return Period (Recurrence Interval)

Return period or Recurrence interval is the average interval of time within which a given magnitude is expected to be equaled or exceeded at least once. 100-year earthquake is an earthquake that is expected to occur, on the average, once every 100 years, or has a one percent chance of occurring each year.

3. RESULTS AND DISCUSSION

The results of the study are as shown (Table 1 to Table 4 and Fig.2 to Fig. 4).

Table 1 shows the inventory of historical/instrumental earthquakes in Nigeria; Table 2 shows the number of earthquake events, minimum magnitude, range and maximum magnitude from 1933 to 2018. The year 1933 is omitted because the magnitude was not stated.

Fig. 4 indicates the earthquake magnitude and return period. It is observed that the return period for an earthquake of magnitude 6.5 on Richter's scale is 86 years, an earthquake of magnitude 4.7 is 34.4 years; an earthquake of magnitude 4.2 is 17.2 years and earthquake of magnitudes 2-3.7 is between 5.55-14.33 years (Table 3). This implies that Nigeria may not likely experience any earthquake of magnitude 6.5 till the year 2025 since earthquake of magnitude 6.5 last occurred in 1939 but the probability of occurrence is 1.16% or 0.0116.

Equation (7) was applied for earthquakes of highest magnitudes which indicate the most hazardous in the location. Equation (8) was used for earthquakes of magnitude 6.5, 4.7 and 4.2 on Richter's scale with probabilities 1.16%, 2.91% and 4.65% (Table 4 and Fig. 5). It is observed that as the time increases the probability of occurrence of these earthquakes increases with it and vice versa with magnitude 4.2 having (99.1%), magnitude 4.7 having (94.8%) and magnitude 6.5 having (80.07%).

Table 2. Data for the earthquakes in Nigeria

Year	Number of earthquakes	Minimum magnitude	Maximum magnitude	Range	Maximum magnitude
1939	1	6.5	6.5	6.5-6.5	6.5
1963	1	2	2	2.0-2.0	2
1981	1	2	2	2.0-2.0	2
1982	1	2	2	2.0-2.0	2
1984	4	2	3.3	2.0-3.3	3.3
1985	1	2	2	2.0-2.0	2
1986	1	2	2	2.0-2.0	2
1987	3	2	2.7	2.0-2.7	2.7
1988	1	2.7	2.7	2.7-2.7	2.7
1990	1	3.7	3.7	3.7-3.7	3.7
1994	1	4.2	4.2	4.2-4.2	4.2
1997	1	2	2	2.0-2.0	2
2000	4	2	4.7	2.0-4.7	4.7
2001	1	2	2	2.0-2.0	2
2002	1	2	2	2.0-2.0	2
2005	1	2	2	2.0-2.0	2
2006	1	2	2	2.0-2.0	2
2009	1	2	2	2.0-2.0	2
2011	1	4.7	4.7	4.7-4.7	4.7
2016	4	2	2	2.0-2.0	2
2018	1	2.7	2.7	2.7-2.7	2.7

Table 3.Rank m, the probability P and the return period T for the data of the annual maximum magnitude

Rank,m	Year	Maximum Magnitude M_L	P=100/T	T=(n+1)/m	T	P
1	1939	6.5	1.16	86.00	31.00	3.226
2.5	2000	4.7	2.91	34.40	12.40	8.065
2.5	2011	4.7	2.91	34.40	12.40	8.065
4	1994	4.2	4.65	21.50	7.75	12.903
5	1990	3.7	5.81	17.20	6.20	16.129
6	1984	3.3	6.98	14.33	5.17	19.355
8	1987	2.7	9.30	10.75	3.88	25.806
8	1988	2.7	9.30	10.75	3.88	25.806
8	2018	2.7	9.30	10.75	3.88	25.806
15.5	1963	2	18.02	5.55	2.00	50.000
15.5	1981	2	18.02	5.55	2.00	50.000
15.5	1982	2	18.02	5.55	2.00	50.000
15.5	1985	2	18.02	5.55	2.00	50.000
15.5	1986	2	18.02	5.55	2.00	50.000
15.5	1997	2	18.02	5.55	2.00	50.000
15.5	2001	2	18.02	5.55	2.00	50.000
15.5	2002	2	18.02	5.55	2.00	50.000
15.5	2005	2	18.02	5.55	2.00	50.000
15.5	2006	2	18.02	5.55	2.00	50.000
15.5	2009	2	18.02	5.55	2.00	50.000
15.5	2016	2	18.02	5.55	2.00	50.000
85 Years					30years	

Table 4. Earthquake probability for some earthquake magnitudes in a time span period

Number of years	Mag 6.5	Mag 4.7	Mag 4.2
0	0	0	0
10	14.89580182	25.57051553	37.88350047
20	27.57275452	44.60251842	61.41540486
30	38.36137347	58.76794005	76.03260014
40	47.54294112	69.31119035	85.11229018
50	55.35684065	77.15847719	90.7522758
60	62.00679719	82.99917233	94.25563744
70	67.66618939	87.34637161	96.43180306
80	72.48256974	90.58196962	97.78356096
90	76.58151162	92.99020854	98.62322566
100	80.06988323	94.78264836	99.14479597

A homeowner living is an earthquake prone area, for example, southern Nigeria will want to know how the risk varies during a period of 30 years. Fig. 6 shows the earthquake probability and the magnitude in time span of 30 years. It is found that the earthquake of magnitude 2.0 has 50% probability of occurrence, 2.7 magnitude (25.81%), magnitude 3.3 (19.41%), magnitude 3.7(16.1%), magnitude 4.7(8.07%) and magnitude 6.5(3.23%) (Fig. 6). This implies that the probability of earthquake occurrence decreases as earthquake magnitude increases. Therefore earthquake of magnitude 2.0 has a higher probability of occurrence than earthquake of magnitude greater than 4.7. But one has to be cautious because earthquakes are naturally unpredictable. Nigeria is not prone to seismic activities but the frequency of the occurrences has been on the rise in recent times due to changes in tectonic activities and increased human interaction with the earth's surface.

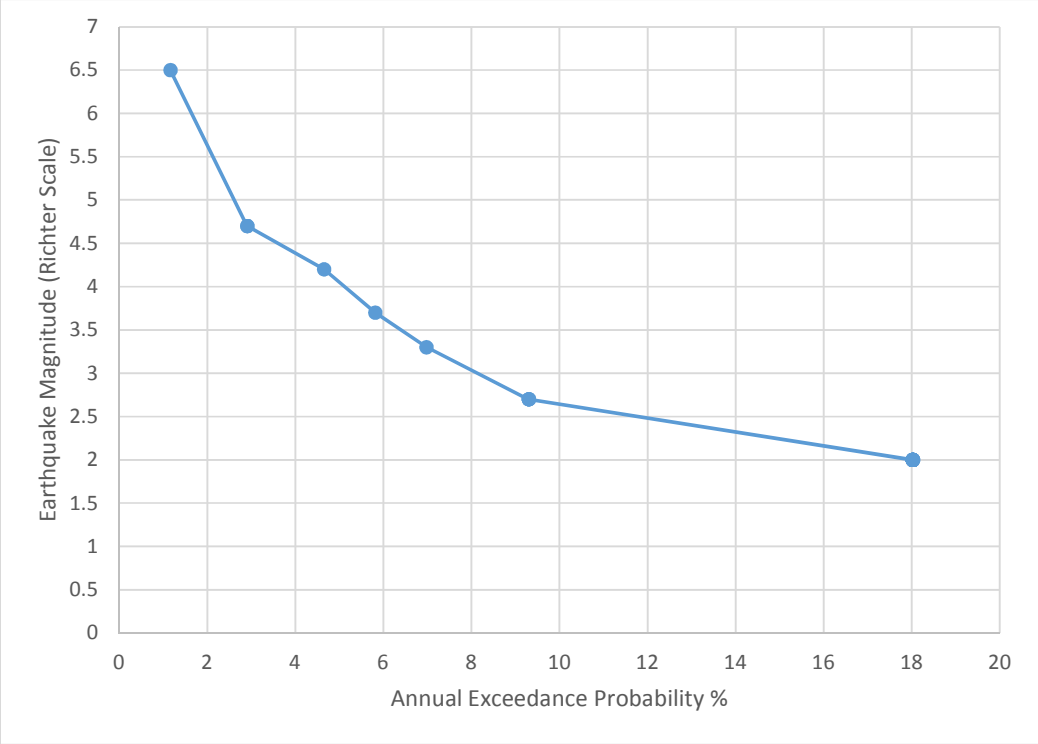

Fig. 3. Earthquake magnitude and annual exceedance probability relationship

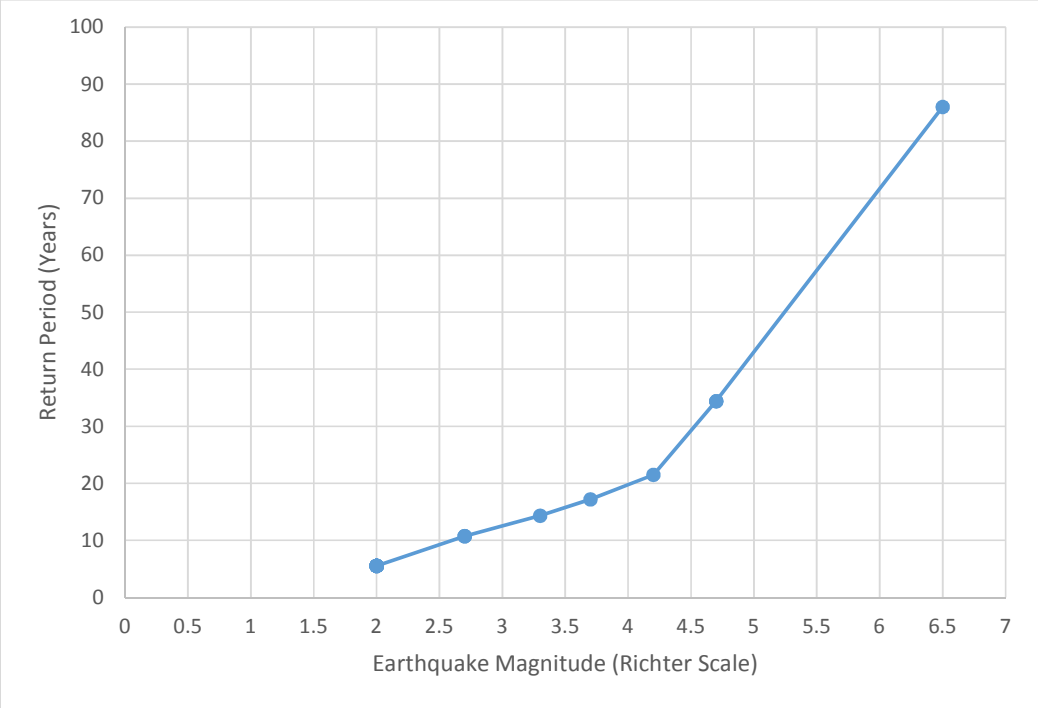

Fig. 4. Return period and earthquake magnitude relationship

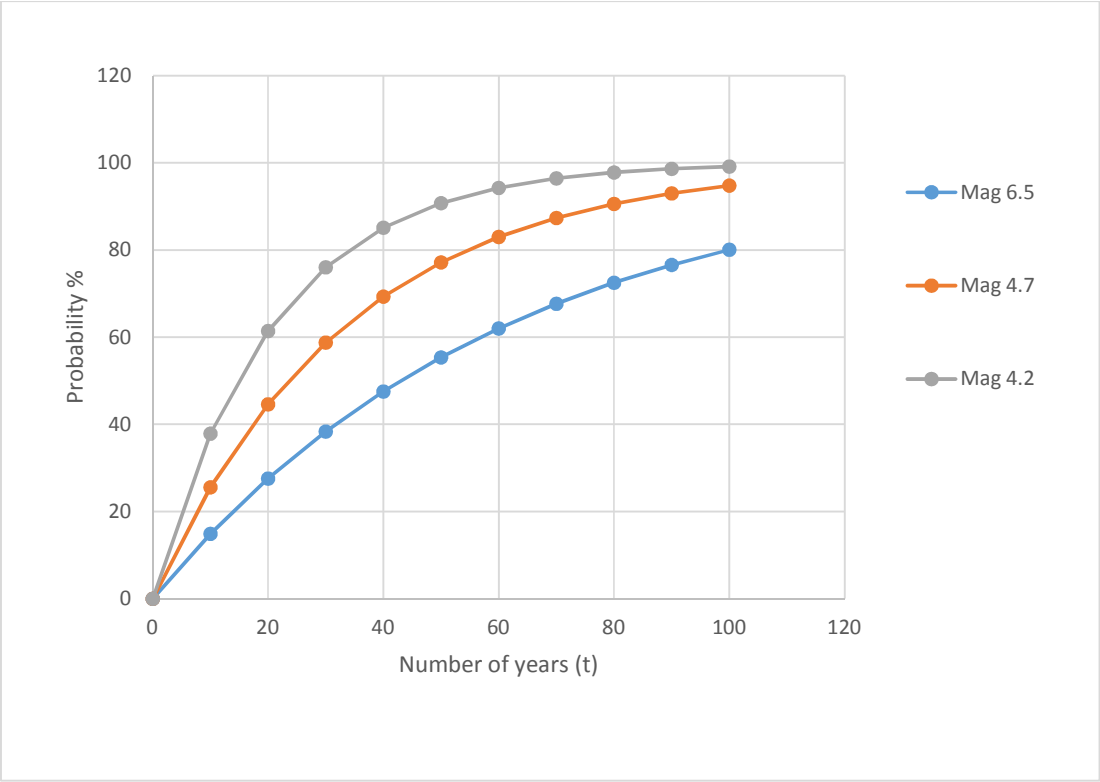

Fig. 5. Earthquake probability for some earthquake magnitudes in a time span period

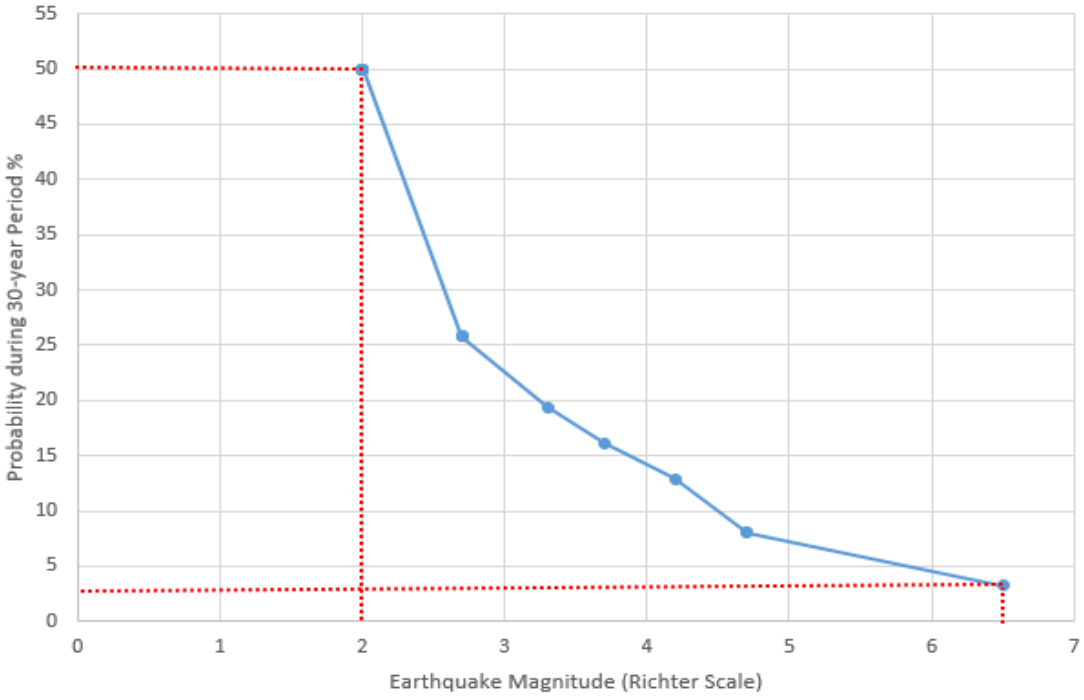

Fig. 6. Earthquake probability and earthquake magnitudes in a time period of 30 years

4. CONCLUSION

This study investigated earthquake occurrences in Nigeria using the Weibull using historical and instrumental data recorded from 1933 to 2018. The findings of the study revealed that the return period for an earthquake of magnitude 6.5 on Richter's scale is 86 years; an earthquake of magnitude 4.7 is 34.4 years; an earthquake of magnitude 4.2 is 17.2 years and earthquake of magnitudes 2 - 3.7 is between 5.56 -14.3 years. But earthquake cannot be predicted with certainty because the concept of earthquake forecast or prediction is still a complicated issue due to saturation of earthquake magnitudes and variation in seismic data collection by different seismic stations and networks. The implication of this study is that the findings of this study will help Nigeria government to protect its people, infrastructures and the constructions that are going to take place especially earthquake – prone areas like south western Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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