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Spatial and Temporal variation of seismic hazard parameter across the Circum Pacific Zone

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Abstract: *Spatio-temporal distribution of earthquakes and variation of seismic b value in the circum pacific zone has been investigated with a view, to identify and understand the seismicity patterns associated with major earthquake in the zone. The earthquake catalogue of the zone from 1899 to 2009 has been analyzed and gridded into subzones. Events in each region were divided into constant time intervals and annular width of 100 km for the investigation of temporal and spatial distribution of the earthquakes respectively. The moment magnitude Mw was employed in this study and other magnitude types were converted to Mw. The b-values were determined from Gutenberg-Richter law using the linear curve fitting method. The result shows an increase in b values at some period while a decrease in b values were observed at other instance The long term variation employed in this research across the regions within the circum pacific zone reveals a pattern of b values that is repeatedly wavy or undulating but not periodic.*

Keywords: *b-value, Seismicity, Seismic Hazard, Spatio-Temporal pattern, Great earthquake*

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I. Introduction

The b – value is defined as the slope of frequency – magnitude distribution of earthquakes. It is an important seismic parameter for characterizing seismicity, hazard analysis and physical understanding of earthquakes. It can be used to study earthquake evolution process and its temporal variation as earthquake precursor[1], [2], [3] It can be used to compute the probable occurrence of earthquake of magnitude M [4], [5], [6], [7], [8], [9] and the mean return period of an earthquake [10] various researches on spatial and temporal variations of the b-value have been carried out in numerous tectonic seismicity studies [11], [12], [13], [14], [15],[16] and induced seismicity studies [17], [18]. Laboratory experiments have shown that the b value decreases linearly with differential stress [12] and changes in b-value are believed to be inversely related to changes in the stress level [19], [20] such that an increase in stress results in decrease of b-value and a smaller b-value implies that the stress is high in the seismogenic volume [21], [22], [23].

II. Data Acquisition And Treatment

The database used in this study was obtained from Earthquake catalogue of Advanced National Seismic System (ANSS), Northern California Earthquake Data Centre, for the period 1900 to 2009. Events around the study area were divided into constant time interval for temporal distribution while for the spatial distribution, the study area was gridded at annular width of 100km i.e. 0-100km radius, 100-200km radius, 200-300km radius, 300-400km radius, 400-500km radius, 500-600km radius and 600-700km. An earthquake data set must be homogenous [24] hence it is necessary to use a uniform magnitude scale. The moment magnitude Mw was employed in this study and other magnitude types were converted to Mw base on the following empirical relations [25], [26], [27], [28], [29]. Moment magnitude Mw is preferred to other magnitude type because is it not based on instrumental recordings of earthquake but on the area of the fault that ruptured in the earthquake. When mapping b – value or seismicity generally, the estimation of magnitude of completeness Mc is critical [22] the magnitude of completeness Mc is the magnitude where the curve bends or where it deviates from linearity [30], Mc was found manually from the frequency distribution to be around Mw = 2. (Fig 1a and Fig 1b)

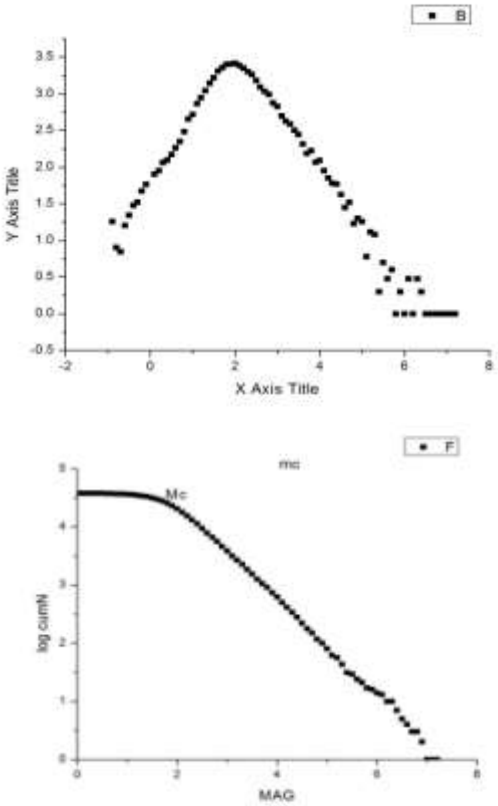

Fig 1a and b: Graphs showing the magnitude of completeness Mc

III. Methodology

The study area was divided into five regions and events in each region were divided into constant time intervals and annular width of 100 km for the investigation of temporal and spatial distribution of the earthquakes respectively. The b values were obtained for each volume of gridded annular width by the linear curve fitting method, using the Gutenberg – Richter law

$$Log_{10} N = a - bM_w \quad (1)$$

where N is the cumulative number of earthquakes, Mw is the magnitude of earthquake, a is a constant that describes the rate of seismic activities while b is the slope of equation (1) known as seismic b value, It is a tectonic parameter for characterizing seismicity, hazard analysis and understanding earthquakes processes and evolution.

$$2 \leq Mc \leq Mw < 8 \quad (2)$$

$$Mw = Mc + n\Delta m \quad (3)$$

$$0 \leq n \leq 59 \quad (4)$$

Where n is an integer and the limit of n is determine by Mc, Δm is the magnitude increment. In this seismic study, Δm is equal to 0.1, this small value was chosen in other to obtain an approximately continuous magnitude. Mc value was determined separately for each region, this ensured that each magnitude group comprise large enough numbers of data.

IV. Results And Discussion

Table 1.1; Temporal variation of b-values for Region 1

T(yr)	b value
1960-1964	0.66572
1965-1969	0.64228
1970-1974	0.75570
1975-1979	0.81079
1980-1984	1.03181
1985-1989	0.75138
1990-1994	0.88528
1995-1999	0.88699
2000-2004	0.70502
2005-2009	0.94625

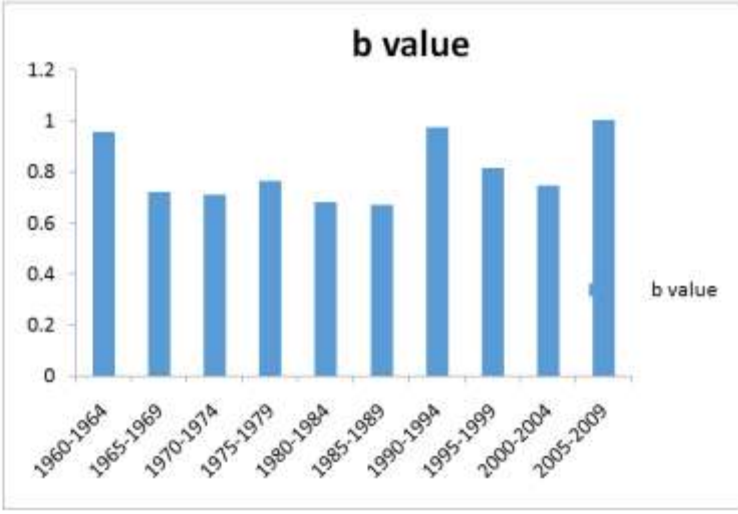

Fig. 2.1: Graphical representation of the temporal variation of b-values for Region 1

Table 1.2; Spatial variation of b-values for Region 1

W(km)	b
0-100	0.73879
100-200	0.79196
200-300	0.88382
300-400	0.80568
400-500	0.74510
500-600	0.67034
600-700	0.70835

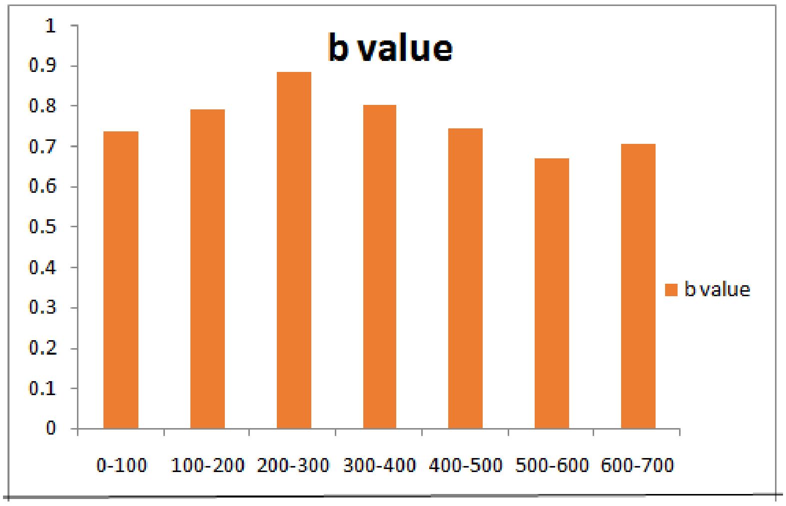

Fig. 2.2; Graphical representation of the spatial variation of b-values for Region 1

Table 1.3: Temporal variation of b-values for Region 2

T(yr)	b
1960-1964	0.7700
1965-1969	0.8400
1970-1974	0.8200
1975-1979	0.8980
1980-1984	0.8133
1985-1989	0.8796
1990-1994	0.9290
1995-1999	0.8710
2000-2004	0.7980
2005-2009	0.8780

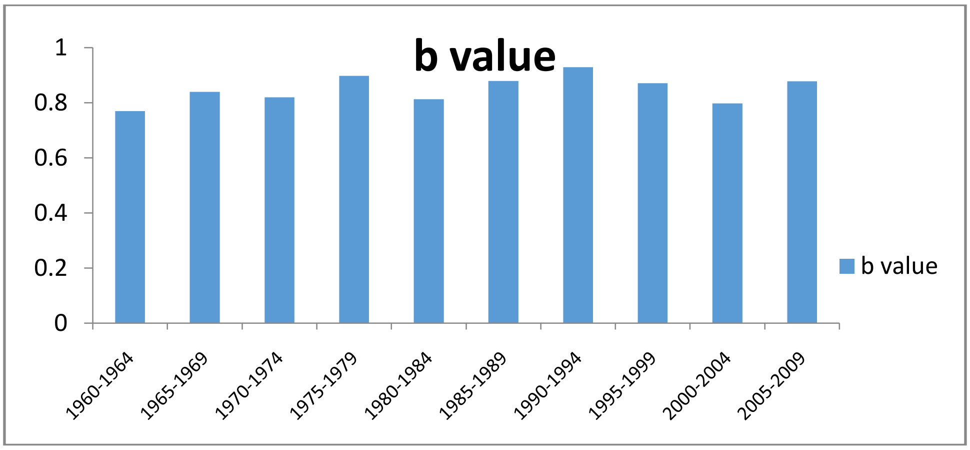

Fig. 2.3: Graphical representation of temporal variation of b-values for Region 2

Table 1.4: Spatial variation of b-values for Region 2

W(km)	b
0-100	0.72213
100-200	0.78178
200-300	0.84293
300-400	0.81273
400-500	0.75243
500-600	0.73390
600-700	0.73790

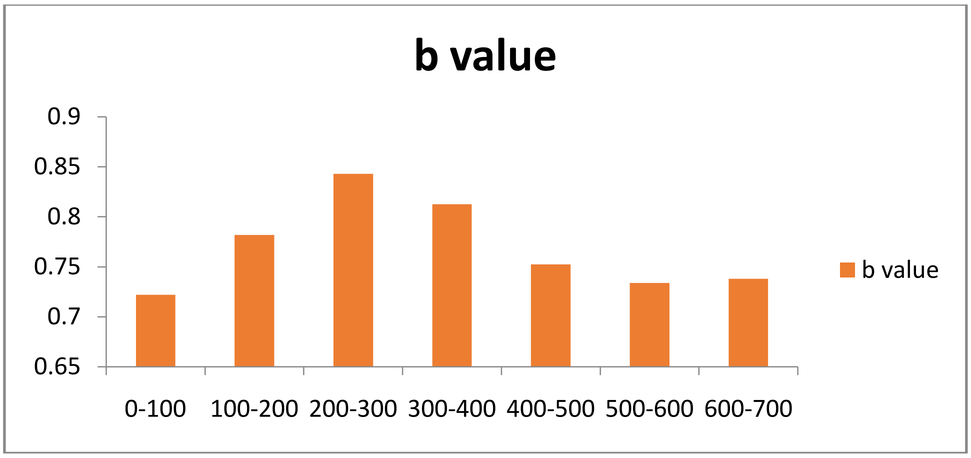

Fig. 2.4: Graphical representation of spatial variation of b-values for Region 2

Table 1.5: Temporal variation of b-values (1960-2009) for Region 3

T(yr)	b
1960-1964	0.7900
1965-1969	0.8800
1970-1974	0.8800
1975-1979	0.9630
1980-1984	0.8600
1985-1989	0.9503
1990-1994	0.8369
1995-1999	0.9630
2000-2004	0.9130
2005-2009	0.9700

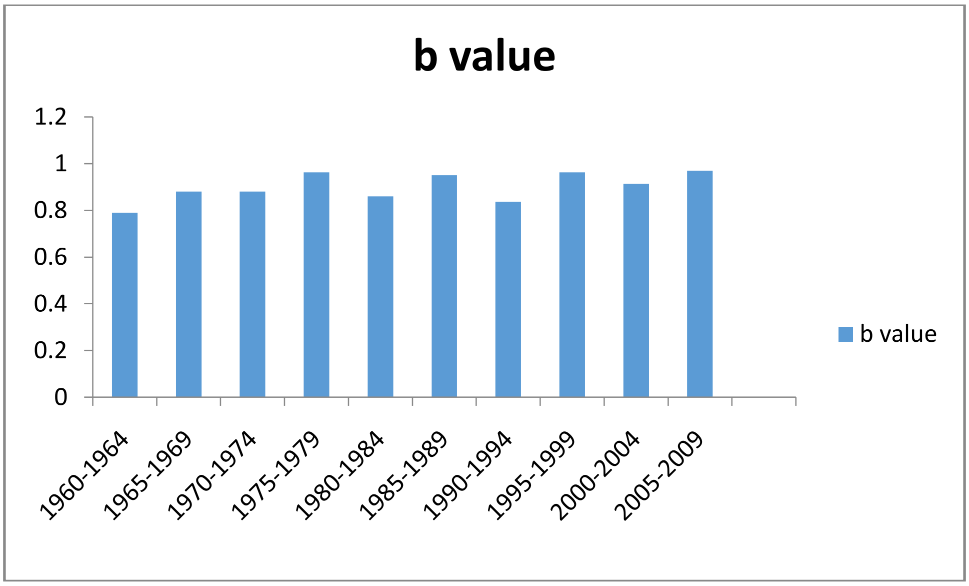

Fig. 2.5: Graphical representation of temporal variation of b-values for Region 3

Table 1.6: Temporal variation of b-values in Region 3 from 1963 to 1978

T(yr)	b value
1963-1964	0.8190
1965-1966	1.0457
1967-1968	0.8854
1969-1970	0.8661
1971-1972	0.7120
1973-1974	0.8967
1975-1976	1.0528
1977-1978	0.8850

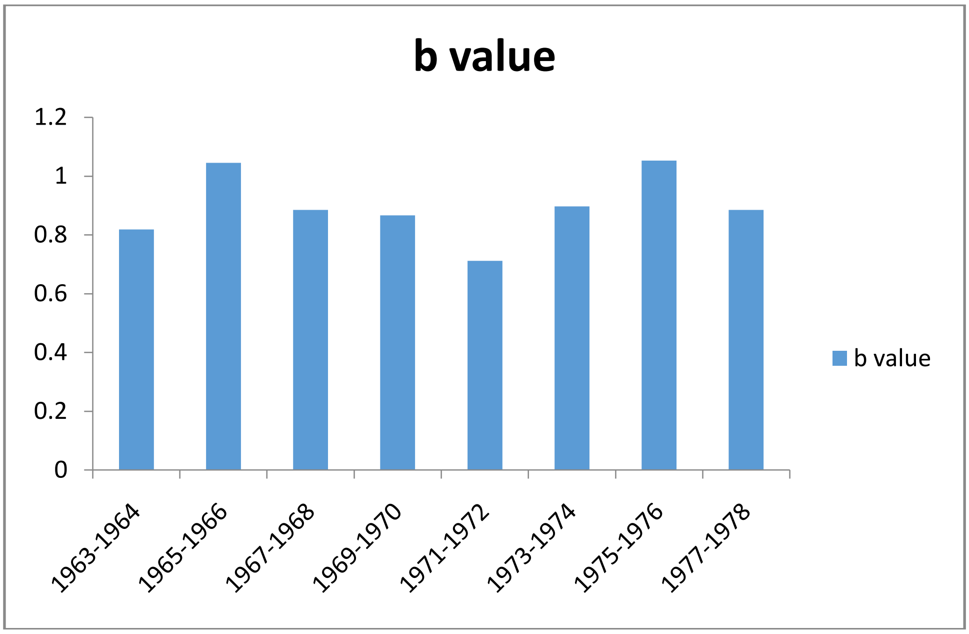

Fig. 2.6: Graphical representation of temporal variation of b-values for Region 3, 1963 to 1978

Table 1.7: Temporal variation of b-values (1978 to 2003) for Region 3

T(yr)	b value
1978-1981	0.9431
1981-1983	0.8424
1984-1986	0.8358
1986-1988	1.0119
1989-1991	1.0337
1991-1993	0.9263
1994-1996	0.8295
1996-1998	1.1258
1999-2001	0.8462
2001-2003	0.8291

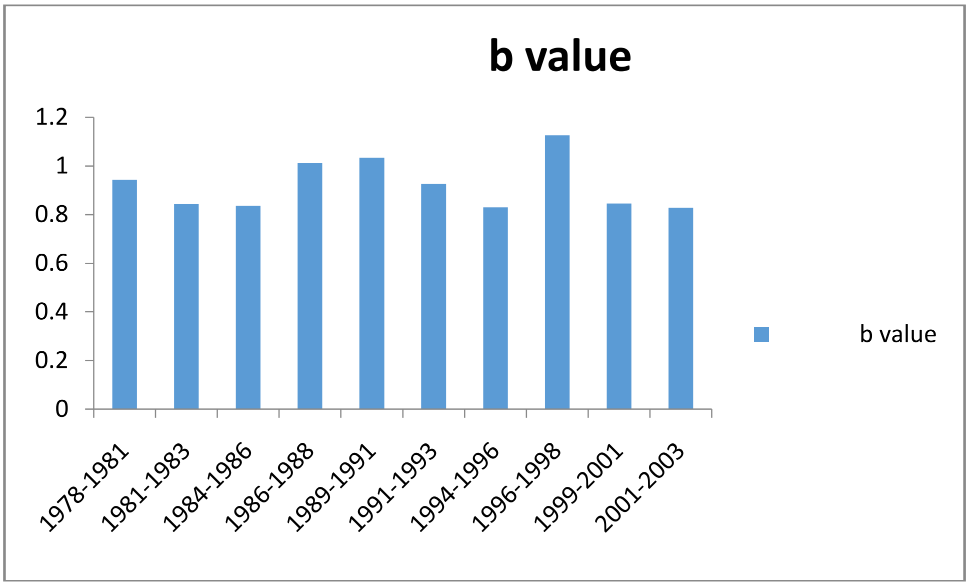

Fig. 2.7: Graphical representation of temporal variation of b-values for Region 3, 1978 to 2003

Table 1.8; Temporal variation of b-values (1960-2009) for Region 4

T(yr)	b value
1960-1964	0.9587
1965-1969	0.7229
1970-1974	0.7105
1975-1979	0.7632
1980-1984	0.6827
1985-1989	0.6705
1990-1994	0.9753
1995-1999	0.8163
2000-2004	0.7478
2005-2009	1.0045

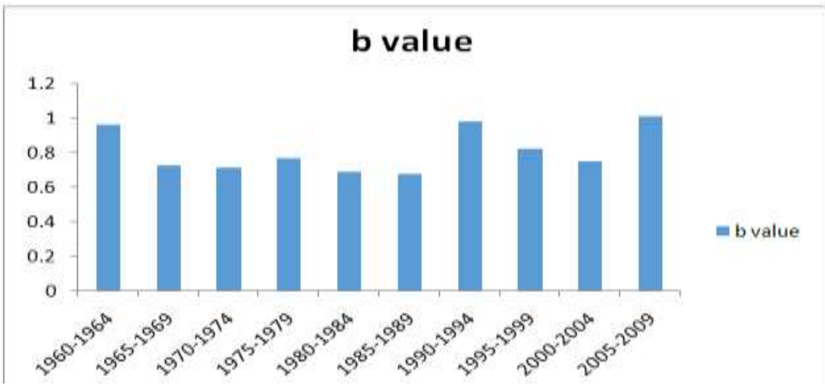

Fig. 2.8: Graphical Representation of temporal variation of b-values for Region 4

Table 1.9: Spatial variation of b-values in Region 4

W(km)	b value
0-100	0.55719
100-200	0.65463
200-300	0.70314
300-400	0.64399
400-500	0.67588
500-600	0.65178
600-700	0.69887

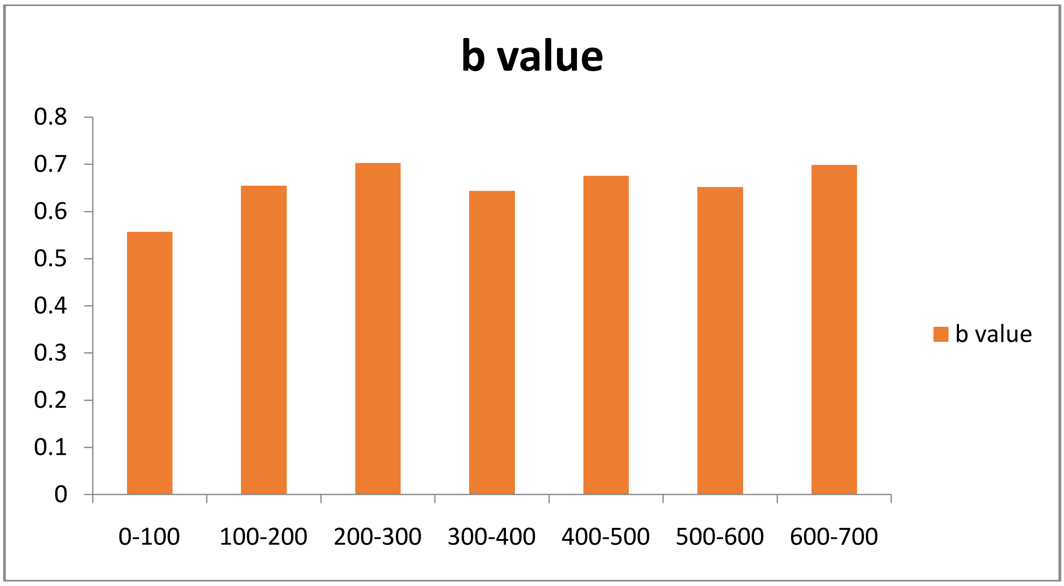

Fig. 2.9; Graphical representation of spatial variation of b-values for Region 4

Table 1.10 Temporal variation of b-values in Region 5

T(yr)	b value
1960-1969	0.55137
1970-1979	0.57661
1980-1989	0.58334
1990-1999	0.78882
2000-2009	0.84018

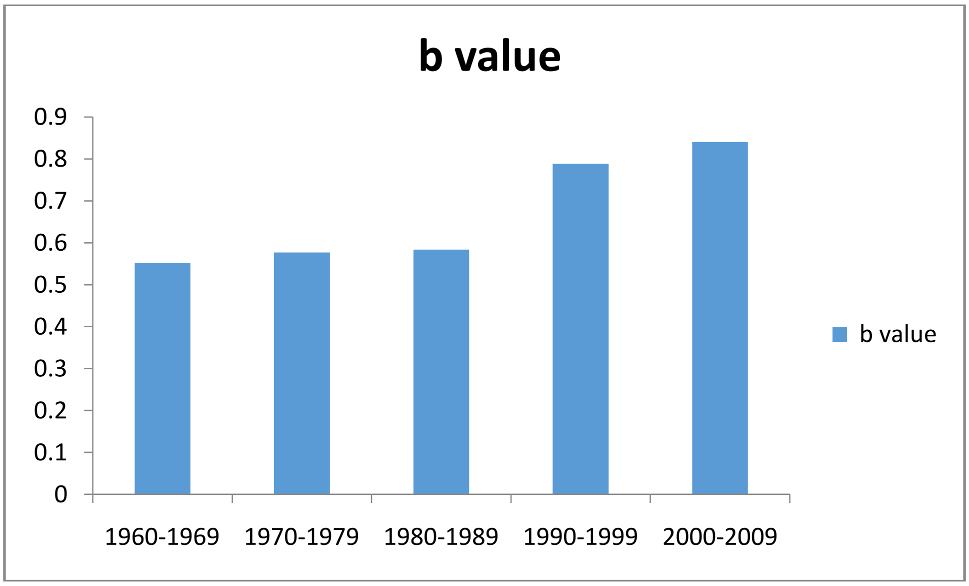

Fig. 2.10; Graphical representation for temporal variation of b values for Region 5

Table 1.11; Spatial variation of b-values in Region 5

W(km)	b
0-100	0.62189
100-200	0.68390
200-300	0.76027
300-400	0.63649
400-500	0.62571
500-600	0.57340
600-700	0.50516

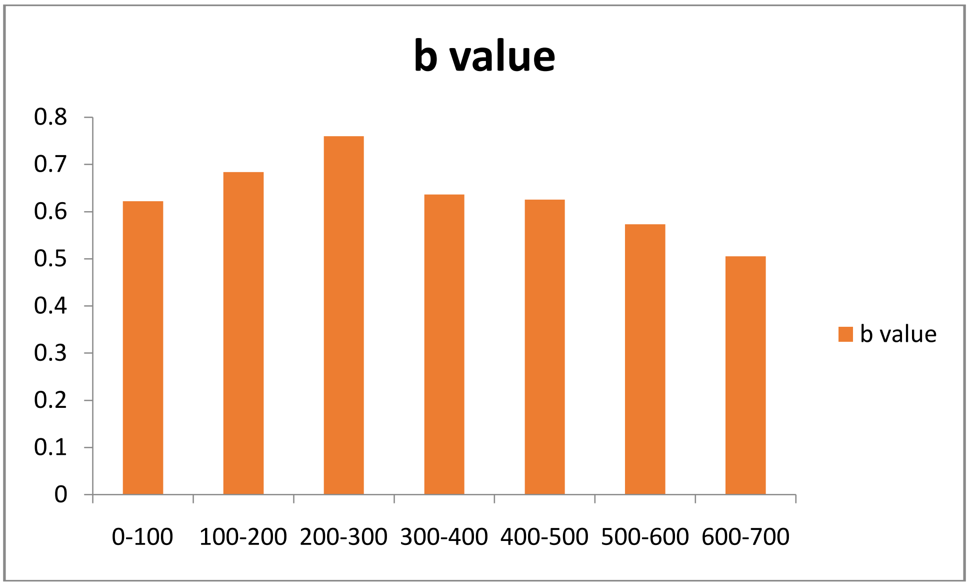

Fig. 2.11; Graphical representation of spatial variation of b values for Region 5

4.1 Region 1

The result for temporal variation of b values Table 1.1 showed an increase from 0.64228 in 1965 - 1969 period to 1.03181 in 1980 to 1984 period for Region 1 while the spatial variation Table 1.2 has the least value of 0.67034 for the volume within 500 - 600km annular width and the highest value of 0.88382 within 200 to 300km annular width. Figure 2.1 is the graphical presentation of the temporal variation of Table .1 while Figure 2.2 is the graphical presentation of Table 1.2 for the spatial variation. These revealed an undulating pattern for the temporal and spatial variation of b value, it also showed that the b value varies temporally and spatially.

4.2 Region 2

Table 1.3 and Table 1.4 showed the results for temporal and spatial variation of b values for Region 2 respectively. There was an increase from 0.7700 in 1960 - 1964 period to 0.9290 in 1990 to 1994 period for the temporal distribution while the spatial distribution has the least value of 0.72213 for the volume within 0 - 100km annular width and the highest value of 0.84293 within annular width 300 to 400km annular width. Figure 2.3 is the graphical presentation of the temporal variation in Table 1.3 while Figure 2.4 is the graphical presentation of Table 1.4 for the spatial variation, the results shows that the b value varies temporally and spatially.

4.3 Region 3

Table 1.5 shows the temporal variation of b-value on a 5 year interval from 1960 to 2009 for Region 3. The lowest value of 0.7900 was obtained within the period 1960 to 1964 while the highest value 0.9700 was obtained in 2005 to 2009. Two temporal volumes 1975 to 1979 and 1995 to1999 have the same b value of 0.9630. The graphical presentation in Figure 2.5 shows a non linear variation of b value. Table 1.6 shows the b values extracted from the Gutenberg-Richter Distribution between 1963 and 1978. This volume is sandwiched between two large earthquakes of 1963 and 1978, the b values ranges from 0.7120 to 1.0528 the lowest was obtained in the period 1971 to 1972 and the highest was obtained in 1975 to 1976. The time interval for this volume is 2 years. The highest value is slightly different from that of 1965 to 1966 (1.0457). The graphical presentation of Table 1.6 is shown in Figure 2.6.

Table 1.7 showed the temporal variation of b values on a 2.5 years interval from 1978 to 2003. This period of 1978 to 2003 is between two large earthquakes of 1978 and 2003 within the region. The lowest value of 0.8291 was obtained within the period 2001 to 2003 while the highest value 1.1258 was obtained in 1996 to 1998. The graphical presentation in Figure 1.7 showed a non linear variation of b value.

4.4 Region 4

Tables 1.8 and 1.9 show the result for temporal and spatial variation of b values for Region 4, It showed a least value of 0.6705 in 1985 to 1989 period and highest value of 1.0045 in 2005 to 2009 period. The spatial variation has the least value of 0.55719 for the volume within 0 - 100 annular width and the highest value of 0.70314 within annular width 200 to 300km annular width. Figures 1.8 and 1.9 are the graphical presentation of the temporal and spatial variation of b values for the region.

4.5 Region 5

The result for temporal variation of b values for Region 5 is showed in Table 1.10. It showed an increase from 0.55137 in 1960 to 1969 period to 0.84018 in 2000 to 2009 period, while the spatial variation in Table 1.11 has the least value of 0.50516 for the volume within 600 - 700km annular width and the highest value of 0.76027 within 200 to 300km annular width. Fig.2.10 is the graphical presentation of the temporal variation in Table 1.10 while Fig. 2.11 is the graphical presentation of Table 1.11 for the spatial variation. These reveals an undulating pattern for the temporal and spatial variation of b values, it also shows that the b value varies temporally and spatially.

V. Conclusion

Increase in b values (mountain - shaped) was observed at some period while a decrease (valley - shaped) or low b values were observed at other instance, the zones of low b – values in the region indicates higher stress, while volume of high b value indicates low stress. The possible explanations for the variation of b-values include heterogeneity, temperature and stress conditions. The long term temporal variation employed in this research shows a pattern of b values that is non linear, repeatedly wavy or undulating but not periodic.

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