A NOVEL GIS BASED SEISMIC HAZARD ASSESSMENT IN ODISHA, INDIA

Ratiranjan Jena, Biswajeet Pradhan *

The Centre for Advanced Modelling and Geospatial Information Systems (CAMGIS), Faculty of Engineering and Information Technology, University of Technology Sydney, 15 Broadway, Ultimo NSW 2007
* Correspondence: biswajeet24@gmail.com or Biswajeet.Pradhan@uts.edu.au

KEY WORDS: Earthquake; Hazard; PGA; Seismic Amplification; GIS

ABSTRACT: This research was conducted to analyse and estimate the PGA (Peak Ground Acceleration) and seismic amplification of Odisha state in India by using earthquake events recorded by USGS (US geological survey) of the region from the year 1950 to 2015. The analysis also includes for an approximately a range of 300 km from every side of state. Many attempts have been proposed to investigate the PGA in this region during the last decades. Therefore, it was a requirement to implement various methods using some recent viewpoints and methodological approaches. Furthermore, research approaches on seismic hazard analysis need to be updated for currently experienced seismic events. Therefore, the objectives of this research focusing; 1) to ensemble various attributes of seismic events for graphical investigation and, 2) to prepare hazard maps using PGA based on a distinctive GIS approach. Our results clearly showed that the region of Odisha is seismically active and there exists the hazard of ground shaking. It also provides a very accurate evaluation of seismic hazards including the seismic waves that influences surface of the ground based on the amplification map. These findings can be considered for the rapid improvement in earthquake research during recent decades that attempts to study seismic hazards and risks in Odisha.

1 INTRODUCTION

One of the most devastating natural hazard is earthquake among all natural disasters that threatens life and properties. Researchers around the world have been investigating the scientific understanding of mechanism of fault movements and earthquake occurrences. Till date, there is no accurate way of prediction with 50-60% accuracy in finding the particular location, time and intensity of the events. Geologists, seismologists and researchers mainly focusing on the re-occurrence of seismic events, hazard, vulnerability and risk analysis.

The large amount of energy can be released from an earthquake of magnitude more than 5. Generally, it is due to the displacement of rocks or any other criteria under the ground surface. As we know the rupture in rocks are usually originated a kilometers under the ground surface. Rupture produced seismic waves that is manifested by shaking and displacing the ground surface (Kramer SL 1996). The occurrence of earthquake could lead to other types of disasters such as landslides and volcanic activities (Umar et.al 2014). Recently deposited unconsolidated soil as well as sedimentary rocks mostly causes local seismic amplification. Alluvial deposits generally amplify the waves more other rocks during an event (Giulio et al. 2011). Heterogeneity in unconsolidated sedimentary rocks or soils can also be one of the major causes for trapping of seismic energy that that creates amplification of waves in the subsurface (Ehret and Hannich 2004).

The state Odisha lies along the eastern coast of Indian subcontinent within the latitudes 17°48´ - 22°34´ North and Longitude 81°24´ - 87°29´ East covering an area of about 1,55,842 km^{2}. It has a 480 km long coastline along the Bay of Bengal. Jharkhand in the North, Andhra Pradesh in the South, Chhattisgarh in the West and West Bengal bound it from the North-East side. The state has a large reservation of various minerals. Although it is not seismically active in the recent past, but a few low magnitude of earthquakes have been reported in various parts of the state. Odisha comes under seismic zone III trending NW-SE direction. Geologically, Gondwana rift basin lies across the state and activity along the normal faults in that basin is the major source of intracratonic earthquakes (Gupta et al. 2002). Most of the damage during earthquakes is caused by terms of shaking and building collapse. This intensity depends upon the subsurface geology including soil profile, lithology. Unconsolidated soil-cover causes local amplification of ground motion. Most of the damage during an earthquake is caused by intense ground shaking and building collapse. The intensity of ground motion depends on near-surface geology including lithology and structural features. The amount of ground shaking and building response largely depends upon the earthquake magnitude, intensity, its PGA.

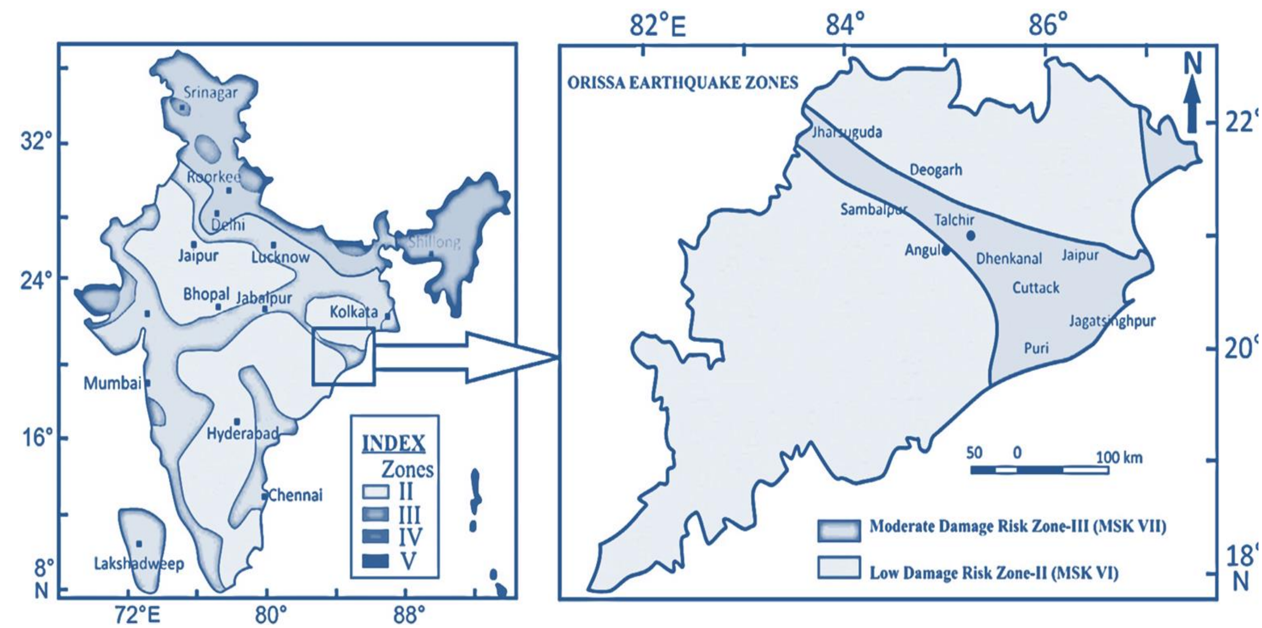


Figure 1 Map showing the seismic zones of Odisha (Pradhan & Jena 2016)

3 DATA AND METHODOLOGY:

3.1 Data

This study was conducted to estimate the peak ground acceleration of Odisha by using earthquake catalogue of the region from the year 1950 to 2015, and for an approximately 300 km distance from every side of this region which covers the longitude of 81°E to 87°E and latitude of 17°N to 23°N. The required data was collected from various sources (USGS, ISC, GSI, and Published Papers).

Table 1 List of earthquakes in the study area (Source: United States Geological Survey, International Seismological Centre)

Sl. no	Date	Latitude(ºN)	Longitude(ºE)	Depth	Mag	Mag Type	Mw	Location	Source
1									

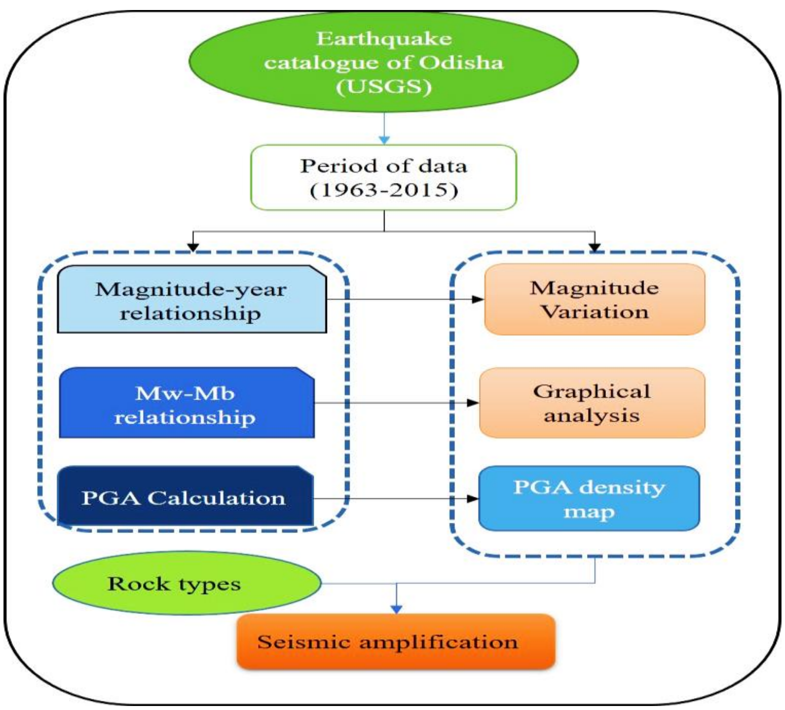
	2014-05-21	18.2012	88.0376	47.23	6	mw	6	Bay of Bengal	USGS
3	2013-08-06	23.3104	88.4902	35.88	4.5	mb	4.7	Gopalganj, West Bengal	USGS
4	2013-06-01	22.02	88.572	10	4.1	mb	4.3	Shyamnagar, West Bengal	USGS
5	2012-08-02	19.564	89.811	10	4.7	mb	5	Bay of Bengal	USGS
6	2009-03-26	22.399	85.903	10	4.1	mb	4.3	Burusai, Jharkhand	USGS
7	2009-02-27	20.473	89.107	10	4.8	mb	5.1	Bay of Bengal	USGS
8	2008-11-08	23.636	87.36	10	4.2	mb	4.4	Madhai Ganj, West Bengal	USGS
9	2008-02-06	23.433	87.111	10	4.3	mb	4.5	West Bengal, India	USGS
10	2003-07-30	21.8	84.3	32	3.4	mb	3.5	Kuchinda, Odisha	ISC
11	2001-06-12	22.223	83.948	33	4.8	mb	5.1	Sundargarh, Odisha	USGS
12	2000-10-16	23.28	80.3	33	4.7	mb	5	Jabalpur, Madhya	USGS
13	2000-10-10	23.08	82.728	33	4.5	mb	-	Rameshwaram, Chhatisgarh	USGS
14	1998-05-22	22.13	84.91	33	4.8	mb	5.1	Rourkela, Odisha, India	ISC
15	1997-05-21	23.083	80.041	36	5.8	mw	5.8	Padwar, Madhya Pradesh	USGS
16	1996-09-25	22	84	32	4.2	mb	4.44	Jharsuguda, Odisha	ISC
17	1996-07-27	18.208	87.433	33	4.7	mb	4.99	Bay of Bengal	USGS
18	1996-02-12	22.616	82.893	33	4.3	ml	4.55	Putka-Devpahadi Range, Chhattisgarh	USGS
19	1995-06-21	21.78	85.327	33	4.7	mb	5	Khandadhar Hills, Odisha	USGS
20	1995-03-27	21.671	84.565	10	4.6	mb	4.88	Sambalpur, Odisha	USGS
21	1993-11-01	21	85.1	33	4.3	mb	4.55	Talcher, Odisha	GSI
22	1993-05-16	23.101	86.982	33	4.6	mb	4.	Indpur, West Bengal	USGS
23	1992-12-08	17.791	86.478	33	4.5	mb	4.77	Bay of Bengal	USGS
24	1991-04-26	20.733	89.563	33	4.7	mb	4.99	Bay of Bengal	USGS
25	1986-03-17	22.87	85.16	10	4.3	mb	4.5	Torpa, Jharkhand	GSI
26	1986-01-19	21.003	85.172	33	4.4	mb	4.6	Talcher, Odisha	USGS
27	1985-07-01	18.367	87.188	10	5.5	mw	5.5	Bay of Bengal	USGS

	1982-10-	20.39	84.42	12	4.7	mb	4.99	Kandhamal, Odisha	ISC
29	1982-04-08	18.519	86.276	24	5.5	mb	5.8	Bay of Bengal	USGS
30	1980-03-30	17.164	81.967	33	4.5	mb	4.77	Korukonda, AndhraPradesh	USGS
31	1979-08-05	22.1	86	22	4.7	mb	5	Odisha-Jharkhand Border	ISC
32	1976-06-23	21.415	88.79	23	5.3	mb	5.	Sundarban coast of West Bengal	USGS
33	1969-04-13	17.747	80.775	20	5.7	mw	5.7	Aswapuram, Telangana	USGS
34	1963-05-08	21.7	86	33	5.2	mb	5.5	Bhaliadiha, Mayurbhanj	GSI

3.2 Methodology

The methodology is designed based on the deterministic Seismic Hazard assessment approach (DSHA) described in the figure 2. In the First step, the collected data was shortened to magnitude more than 4. Since, the highest magnitude recorded was 6 therefore, the calculation was included with all the event magnitudes ranging between 4-6. Literature survey for historical and recent earthquakes has been conducted to investigate the earthquake magnitudes with locations in the study area. This step was done for better interpretation and understanding of the spatial distribution, identification of historical zones and recent seismicity. Modelling the cross section of Mahanadi Graben helps to understand the sediments types and their relation with normal faults. The relation with seismic zonation map and earthquake distribution is also important to describe the percentage of hazardous area. The details of the methodology has been described in the figure 2 presented below.

Figure 2 Overall methodological flowchart of the study.



4 RESULTS AND DISCUSSION

4.1 Magnitude variation

The spatial distribution of earthquakes in Odisha can be found with very less magnitudes. However, earthquakes experienced in Odisha can be found as low as 2.5 up to a maximum magnitude of 6. Ninety percent of the earthquakes that happened in Odisha are located in Mahanadi Graben that is coming under the seismic zone III. The recent earthquakes were during 2014 and 2015 with a magnitude of 6 and 4.5, respectively. This clearly represents the active movement of faults in Mahanadi Graben that is characterised by two largest faults such as Mahanadi shear zone and North Odisha boundary fault. Magnitude vs. year graph represents the distribution of various magnitudes experienced in Odisha. It clearly explains the increase and decrease of magnitude with time. The curve in the graph represents the variation of magnitudes with time.

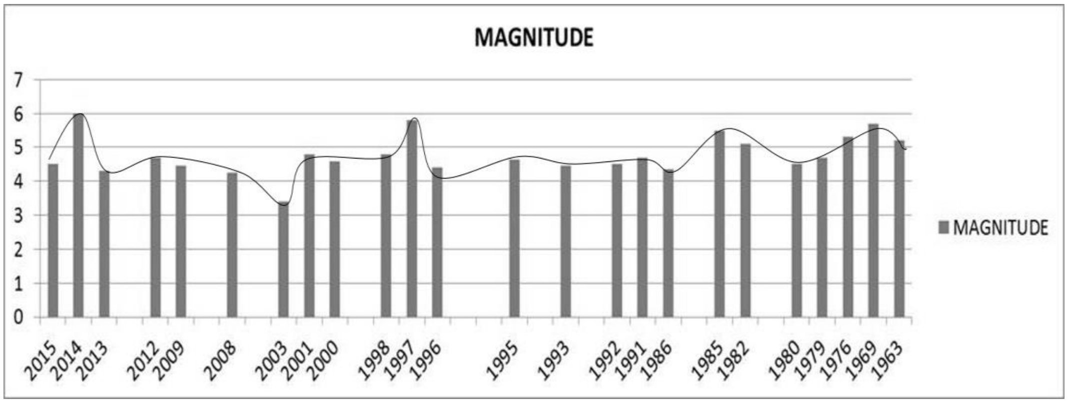


Figure 3 Presents Magnitude vs Year.

Several magnitude scales are approved and used by seismological centers of various countries. In general, available scales are surface wave magnitude scale (Ms), the body wave magnitude scale, (*M*b), and the local magnitude scale, (*M*L). The most reliable and useful scale of magnitude is (*M*w) known as moment magnitude. All the collected data have magnitudes in all formats. So all the data should be converted to a common format (Mw). Various authors have given many methods to convert to a common format. Nevertheless, based on the collected data, the formulas given below are suitable. According to (Yenier et. Al.,)

$$M_w = 1.104 m_b - 0.194,\ 3.5 \leq m_b \leq 6.3 \text{ (for body-wave magnitude)} \quad (1)$$

$$M_w = 0.953 M_L + 0.422,\ 3.9 \leq M_L \leq 6.8 \text{ (for local magnitude)} \quad (2)$$

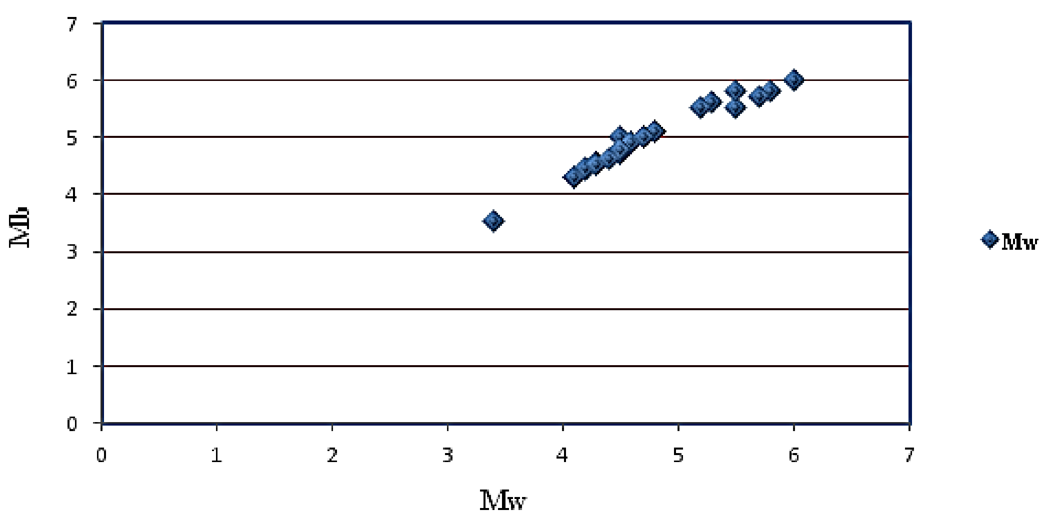


Figure 4 Relationship between Mw and Mb.

4.2 PGA analysis

has been calculated. Hypoenteral distance is defined as the distance between the seismic

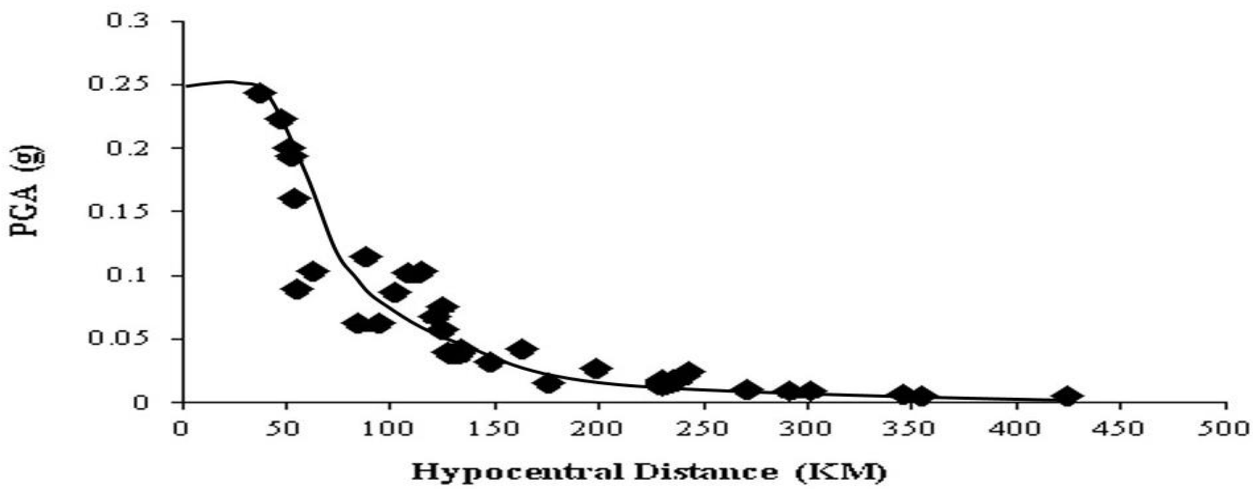


Figure 5 Relationship between PGA and Hypocentral distance.

station and the source. It generally depends upon the velocity of P and S-waves and the velocities of P and S waves depends upon the lithology and its density. Therefore, various formations will show different velocities. Using the hypocentral distance, the PGA values are calculated. (Campbell 2010) proposes for calculation of PGA. Therefore, the results clearly show that PGA values are high at a hypocentral distance of 100km. PGA and the hypocentral distance have been plotted in a graph representing the graphical relationship.

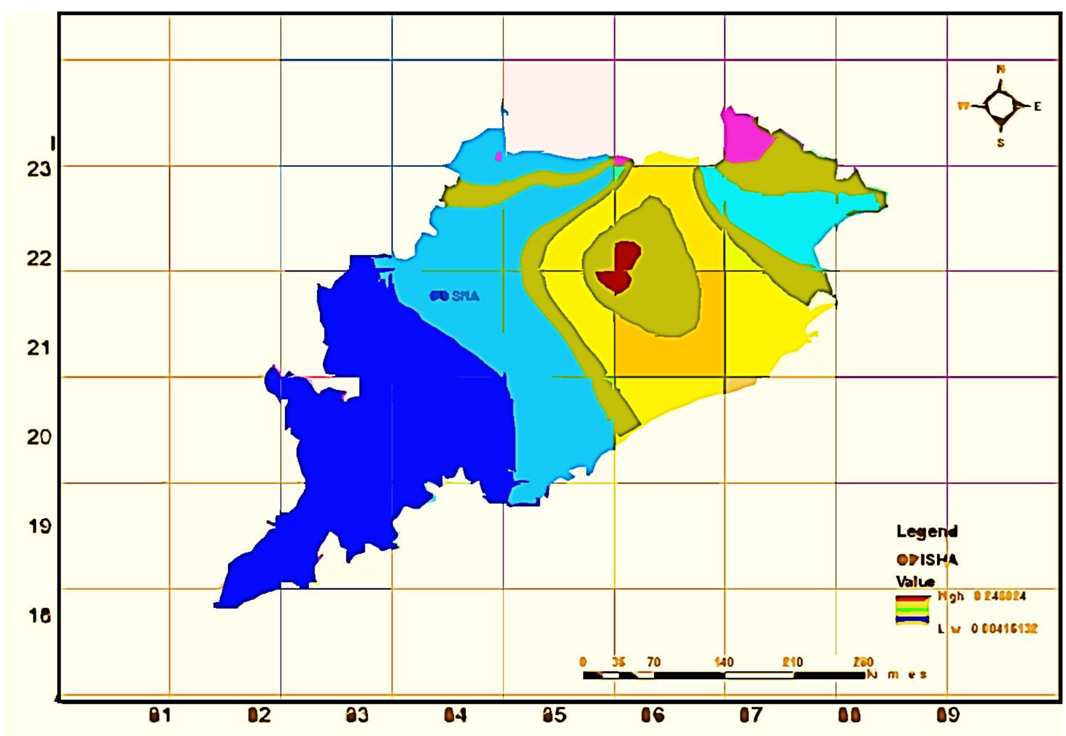


Figure 5 PGA density map of Odisha with highest value 0.2 found in the center.

PGA density map of Odisha has been prepared and presented in the figure 5. PGA density map shows the highest and lowest values in different parts of the state Odisha. Therefore, it shows that the highest values of PGA can be found in the Mahanadi graben characterized by MSZ and NOBF.

is characterized by very low PGA density. The highest values can cover the districts of Cuttack, Bhubaneswar, Angul, Sambalpur, Sundargarh, Rourkela, Jajpur etc. the density of PGA can gives the evidence of the hazard in Odisha. With a magnitude of 6 can be dangerous for the city like Cuttack as it is a city of approximately 200 years old. Therefore, very poor quality city building structures as well as planning can be dangerous for a large populated area.

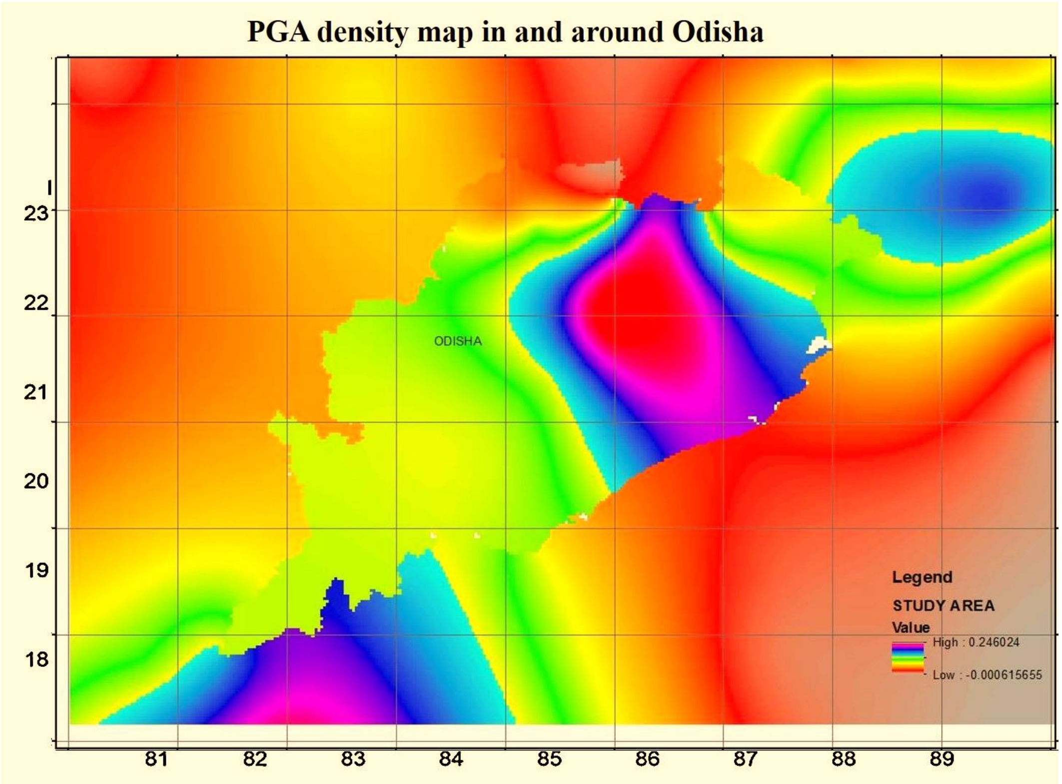


Figure 6 PGA density map of Odisha with seismic amplification and 200 km surrounding the state.

Surrounding the state Odisha, PGA values are presented by using the IDW interpolation technique. The details of the PGA values resulted from the study are presented in the figure 6. There are some high PGA values can be found at the southern part of the state while eastern part of the state has a very low PGA values. Current seismicity has been reported in various parts of Precambrian shield of Odisha. Mechanism of strike-slip faults clearly revealed during the characterization of fault plane solutions modelling (Chandra, 1977). The slip orientation is in the direction of ENE-WSW in association with N-S stress. From the present study, low to moderate size of earthquakes have been reported in Bonaigarh-Talchir area, located along the Singhbhum Craton-EGMB contact zone. Therefore, the PGA values of moderate earthquakes need to be consider while low magnitude of earthquakes cannot do any destruction.

5 CONCLUSION

These findings are very much useful for the rapid development of construction of high-rise buildings and engineering structures. The necessity of recent decades makes many possibilities to analyze and study seismic events in this area.

These earthquake studies are usually characterized and explained in two stages in this research. Therefore, in the first stage, graphical investigation and representation of various seismological attributes to analyze the behavior and characteristics are presented. In the second step, estimation of and other geological and geomorphological characteristics. Any area that is seismically active and the existence of the hazard of ground movement need to be considered based on seismic behavior on infrastructures. The designed model for this study was a novel model to calculate and analyze the PGA values in different parts of the study area. The model is feasible, cost effective and good in accuracy.

References

Kramer, S.L., 1996. *Geotechnical earthquake engineering*. Prentice Hall Upper Saddle River, NJ, Vol. 80.

Boore, D.M., Campbell, K.W., Atkinson, G.M., 2010. Determination of stress parameters for eight well-recorded earthquakes in eastern North America. *Bulletin Seismological Soc of America,* 100, pp.1632-1645.

Ehret, D., and Hannich, D., 2004. Seismic Microzonation Based on Geotechnical Parameters - Estimation of Site Effects in Bucharest (Romania). 2004AGUFM.S43A0972E.

Gupta, H., 2002. A review of recent studies of triggered earthquakes by artificial water reservoirs with special emphasis on earthquakes in Koyna, India. Earth-Science Reviews, 58(3-4):279-310, DOI: 10.1016/S0012-8252(02)00063-6.

Chandra, U., 1977. Earthquake of Peninsular India- A seismotectonic study. Bull. Seis. Soc. Am, 67(5), pp. 1387-1412.

Pradhan, B., & Jena, R., 2016. Spatial relationship between earthquakes, hotsprings and faults in Odisha, India. IOP Conf. Ser: Earth Environ. Sci, 37, 012070, doi:10.1088/1755-1315/37/1/012070.

Giulio, G.D., 2011. Exploring the model space and ranking a best class of models in surfacewave dispersion inversion: Application at European strong-motion sites. Geophysics, 77 (3) pp. B147–b166, 10.1190/geo2011-0116.1.

Yenier. E., Erdoğan, O., & Akkar, S., 2008. Empirical relationships for magnitude and source-to-site distance conversions using recently compiled turkish strong-ground motion database, The 14th World Conference on Earthquake Engineering October, 12-17, Beijing, China.