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Seismic Hazard Assessment by Preparing S1 and Ss maps for Baluchistan Province, Pakistan

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Abstract

Seismic Hazard assessment is essential component for seismic risk analysis, mitigation and emergency management. Researches assessed hazard in the selected parts of Pakistan including Baluchistan province. Seismic Hazard Assessment for Khyber Pukthunkhwa (KPK) province has been previously done on large scale, however no such work has been carried out for Baluchistan province. The seismicity and frequency major earthquakes in Baluchistan province, require detailed Seismic Hazard Assessment. This paper presents the Probabilistic Seismic Hazard Assessment (PSHA) of Baluchistan Pakistan, emphasizing on spectral acceleration parameters. Earthquake loading is defined in terms of 0.2sec and 1.0sec spectral acceleration. Seismic hazard is estimated in terms of Peak Ground Acceleration (PGA) using Earthquake Risk Assessment (ERA) framework. This Framework is developed using Ambarasey's 2005 Ground Motion Prediction Equation for the assessment of hazard. A maximum Peak Ground Acceleration of 1.21 g, occurs in the district of Sibi, while minimum was found in Chaman of 0.03g using 1.0sec (S1) spectral acceleration and 0.65g at Quetta using 0.2sec (Ss) spectral acceleration. Seismic hazard mitigation strategies are recommended depending on the results.

Keywords: Earthquake, Seismic Hazard, spectral acceleration, Ss, S1, Attenuation, Probabilistic Seismic Hazard Assessment, hazard Mitigation, Baluchistan.

1. Introduction

The Seismic hazard assessment at world level has been carried out under the Global Seismic Hazard Assessment Program (GSHAP) (Giardini et al., 1999). The seismic hazard maps for Pakistan have been extruded from world hazard map (Shah, 2012). After the major earthquake of Kashmir and Northern Pakistan in 2005, many researchers and organizations including Pakistan Metrological Department (PMD) and NORSAR (2006) have carried out the seismic study of Pakistan. The Building Code of Pakistan incorporated the seismic provisions, 2007 based on the latest seismic activity in the region and the Peak Ground Acceleration (PGA) values were used for defining various zones in the country (Building Code of Pakistan, 2007).

Baluchistan province of Pakistan is located in the south-west of the country with Quetta as its capital. This province consists of 30 districts with the total population of approximately 6.5 million (PBS, 1998). District wise map of Baluchistan is shown in Figure 1. Devastating effects of earthquake have been witnessed in various districts of Baluchistan. The latest earthquakes of Awaran, Kech in 2013, Quetta, Ziarat, Pishin and Harnai in 2008 and historical earthquakes of Quetta in the region highlighted the need of a seismic hazard assessment at provincial level. Studies on the Seismic Hazard Assessment (SHA) of some selected areas of the Baluchistan province have been conducted by Bhatti (2013), Erduran et al., (2012) and Shah et al., (2012). However large scale SHA study at provincial level is not being carried out for Baluchistan.

Baluchistan is located at the southern front of collision zone. Kirthar mountain range and some portion of Suleiman mountain range makes it seismically active region (Fig. 2). 1935 earthquake at Quetta with a magnitude of 7.0 killed 35000 peoples. Ziarat 2008 earthquake having magnitude of 6.4 affected 117500 populations (UN-HABITAT, 2010). The Awaran 2013 earthquake of 7.7 magnitude affected 185150 populations, and 27030 families (PDMA-Baluchistan, 2013). Hence the earthquakes intensity and frequency in the province has been increased in recent past.

Probabilistic Seismic Hazard Assessment (PSHA) take the following components into consideration i.e. the event (cause, time, and location), the resulting ground motion (amplitude, duration, frequency) and exceedance of particular ground motion with time quantitatively (Khan et al., 2012) developed a computer based toll, Earthquake Risk Assessment (ERA) framework for Probabilistic Seismic Hazard Assessment (PSHA) in developing countries and their seismic conditions and parameters.

The International Building Code (IBC, 2009), defines earthquake loading in terms of 0.2sec and 1.0sec spectral acceleration and the maps developed on its basis are termed Ss and S1 maps respectively. To determine the Ss and S1 maps of Baluchistan province the ERA framework of (Khan et al., 2012) has been used.

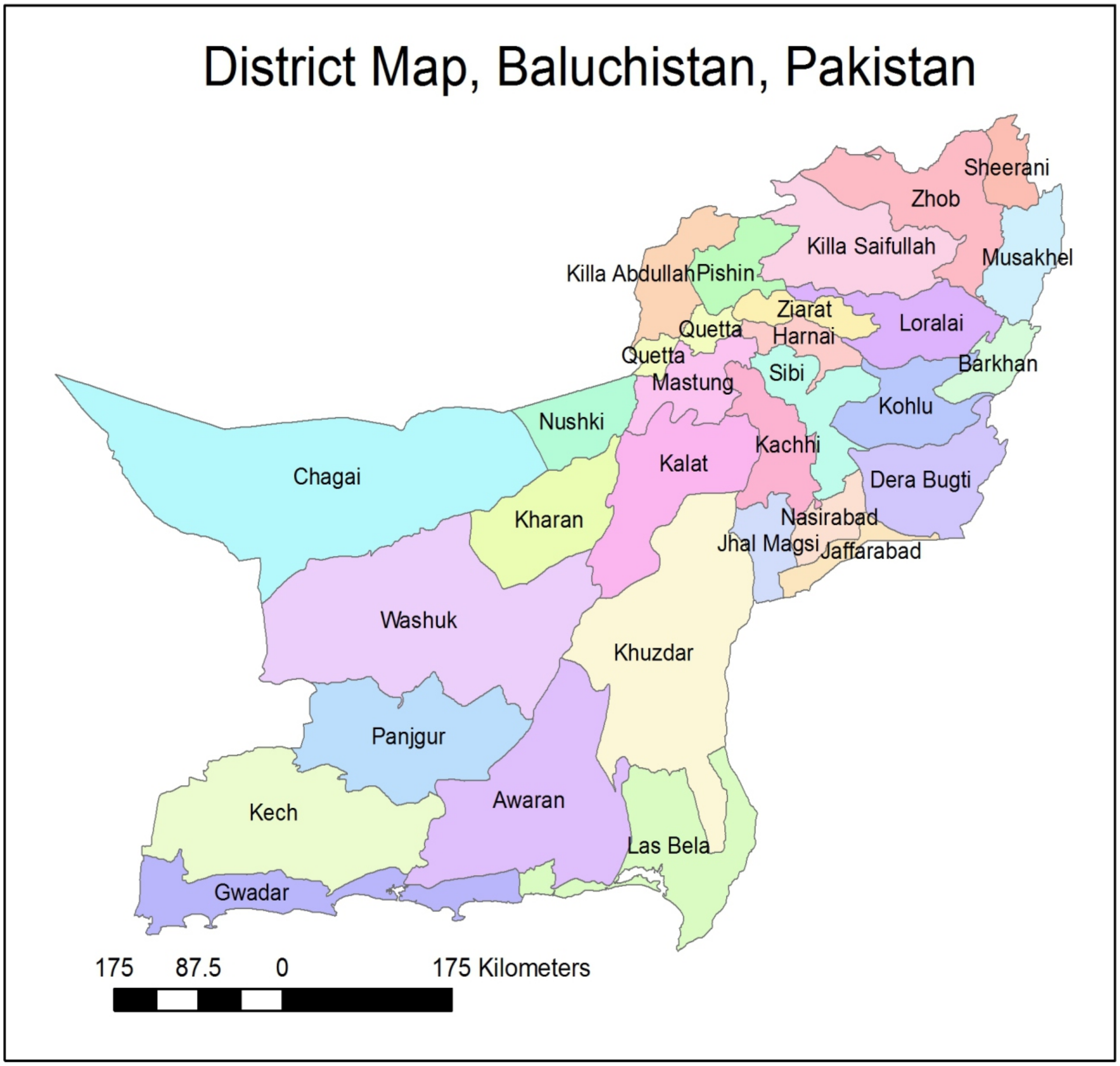

Fig. 1. Study Area-Baluchistan Province. Pakistan (District Wise Map, Government of Baluchistan, 2013).

2. Methodology and Required Data:

In this research, the Seismic Hazard Assessment (SHA) framework is developed only for ground motion effects. The effects of other phenomena like landslides, liquefaction, tsunamis, and release of toxic materials, fire etc. are not included. Seismic hazard is calculated using Probabilistic Seismic Hazard Assessment (PSHA) process (Kythreoti, 2002). ERA framework developed by (Khan et al., 2012) requires minimum input data for SHA. ERA framework is easy to use and is suitable for developing countries with minimal available data to carry out the seismic hazard estimates for various return periods.

Pakistan is located on the western face of Indo-Pakistan sub-continental plate, the northwestern edge of Indian lithospheric plate, southern part of Afghan craton, and the northern part of Arabian oceanic sub-ducting plate (Zaigham et al., 2000). Indian subcontinent collided with Eurasian sub-continent in last 30-40 million years (Aitchinson et al., 2007), resulted various mountain range throughout this period from continental lithosphere, lengthier than 2000km. Northern, Southern, Western Pakistan, Kashmir, Northern India and Afghanistan are situated along high seismic movement zones. Earthquakes occurs along an extremely active thrust fault framework. Figure 2, shows major tectonic features in the region.

PMD-NORSAR (2007) allocated seismic zones, which consists of study area along with surrounding regions shown in Figure 3. These seismic zones are used in this study as key parameter for ERA. Division of seismic source zones in this arrangement is dependent upon seismicity, geology and source mechanism.

To develop the historic data of earthquakes, the past records should be carefully examined as the accuracy of activity rate is totally dependent on the accuracy of earthquake records. All aftershocks and foreshock should be eliminated from the catalogues (Abrahamson, 2006). Statistical analysis of data is required to fit the data on exponential distribution model. Normally these values are calculated using regression analysis.

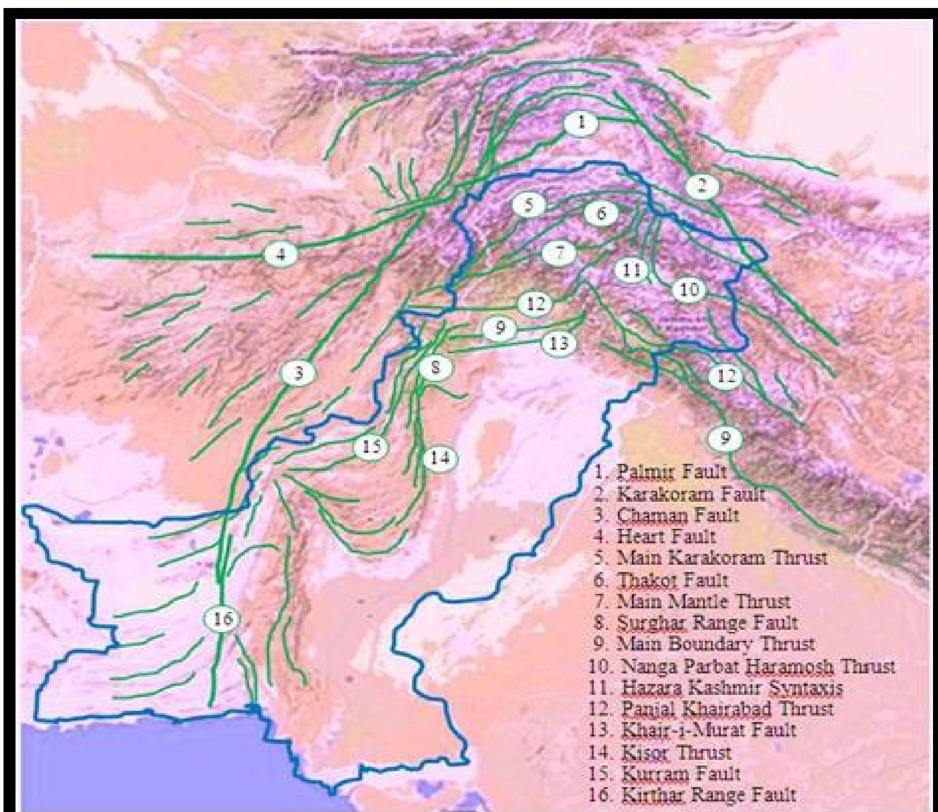

Fig. 2. Major Tectonic features in Pakistan (Khan 2011).

The earthquake records can be divided into two reigns, first before the invention of sophisticated instruments often called as historical earthquakes, second the earthquakes recorded after the invention of sophisticated instruments are known as Instrumental earthquake record. Historical earthquake record for study area is shown in Table 1. Instrumental earthquake record for the region is obtained from International Seismological Center (ISC), shown in Figure 4.

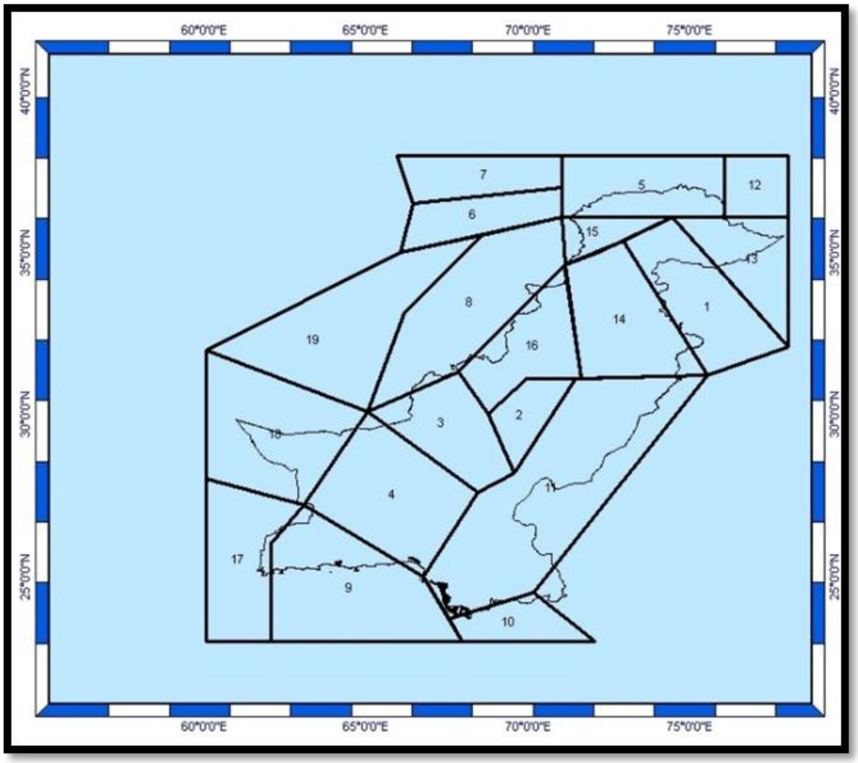

Fig. 3. Seismic source zones of Pakistan. (PMD-NORSAR, 2007).

Table 1. Record of Major Earthquake in Baluchistan by (PMD-2004).

Year	Affected Places	Intensity at Richter's Scale	Year	Place	Intensity at Richter's Scale
1909	Kech	7.2	1987	Quetta, Chaman	5.6
1935	Quetta, Mach	7.0	1990	Quetta, Kalat, Khuzdar, Mastung, Kalat, Nushki, Surab	5.8-6.1
1935	Quetta, Mastung, Kalat	7.5	1992	Khuzdar, Nal, Quetta	5.7
1941	Quetta	5	1993	Quetta/Pishin, Makran/Gwadar	5.7
1945	Pasni/Makran	8.6	1995	Quetta	5.2
1952	Lorelai	5.8	1996	Quetta	5.2
1954	Khuzdar, Nal, Wadh	5.7	1997	Quetta, Mastung, Mach, Sibi, Harnai	5-6.2
1955	Quetta	6	1998	Quetta, Dalbandin	5.3
1956	Kalat, Barkan	6	1999	Barkan	5.2
1957	Khuzdar	5.5	2000	Quetta, Sibi, Ziarat, Harnai and Duki	6
1975	Quetta	5.4	2002	Baluchistan Boarder	6
1978	Quetta, Nushki	5.3	2003	Naukundi, Musa khail	5.3
1983	Khuzdar	6.5	2004	Sibi	5.5
1986	Khuzdar	5.4			

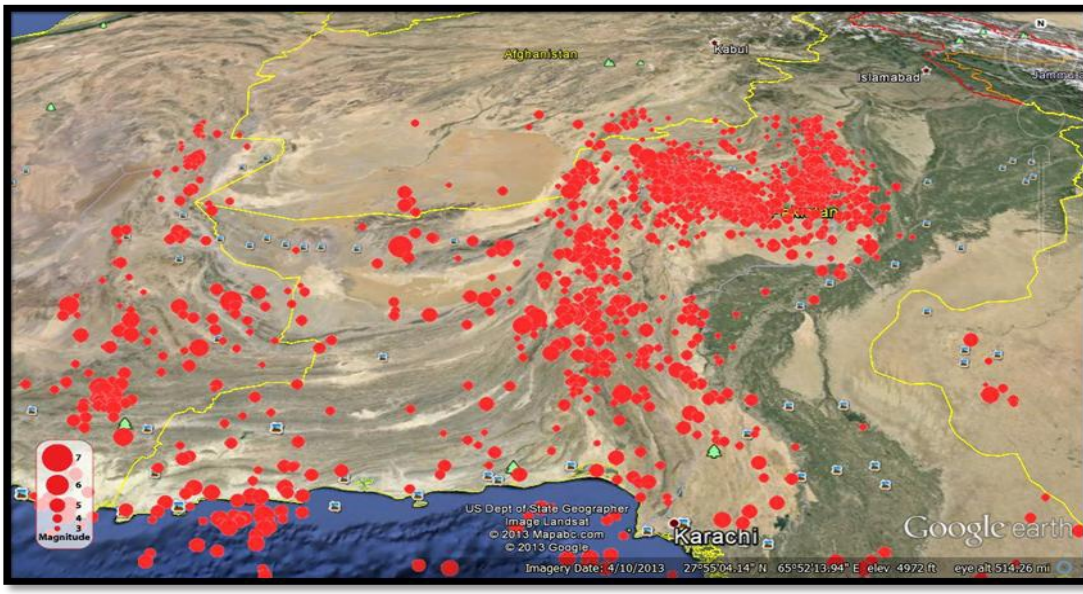

Fig. 4. Spatial representation of instrumental seismicity for Baluchistan (ISC Catalogue, 2014).

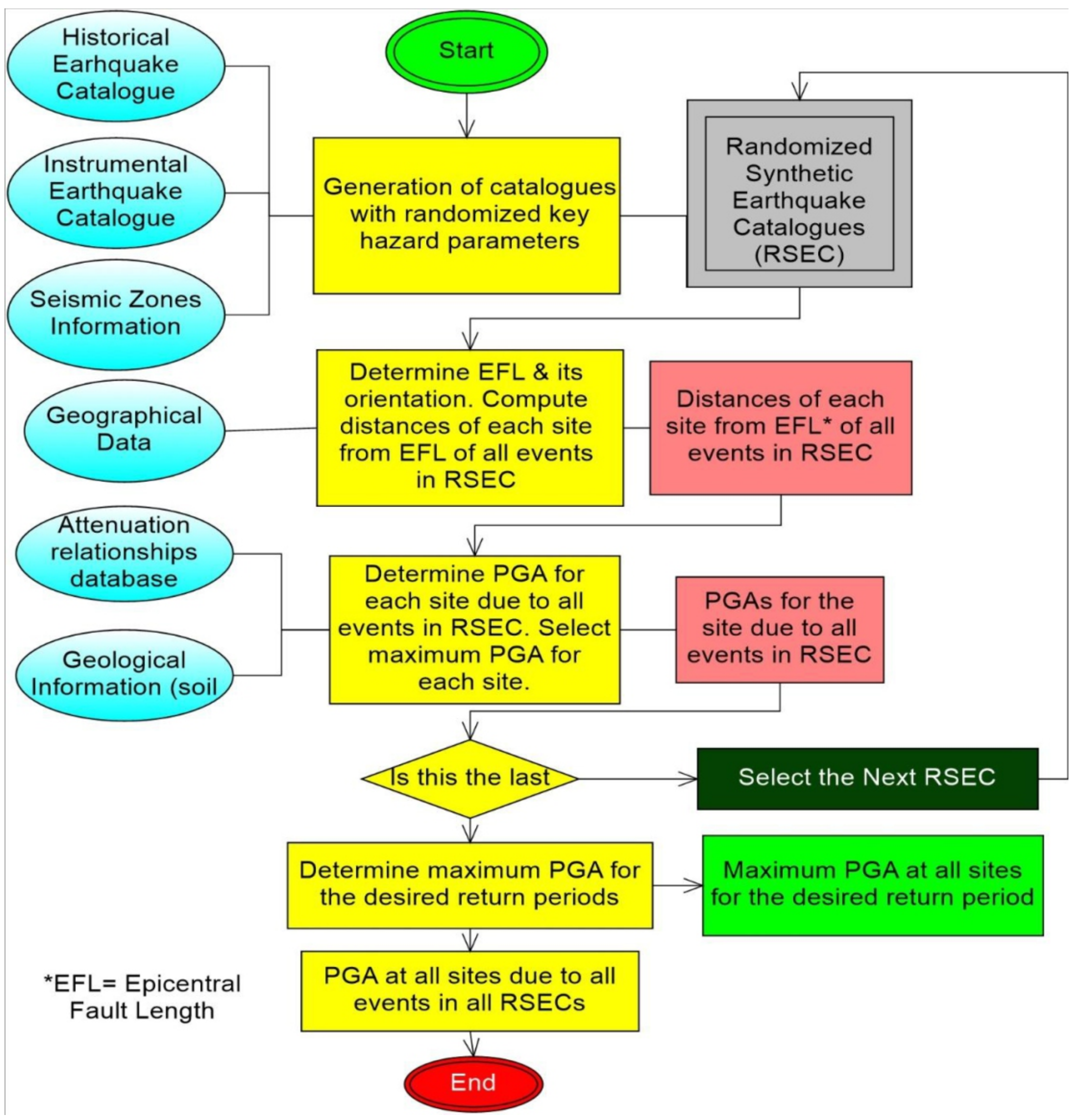

Fig. 5. Summary Probabilistic Seismic Hazard Assessment (PSHA) Procedure/Model (Khan, 2011).

An attenuation relationship is the requirement for calculating ground motion at the site due to an earthquake event at a distance. After detailed study on attenuation equations, it was concluded that there is not a single equation even from nearby countries that can be used for SHA of Pakistan (Monalisa, 2005). For Pakistan there is no specific attenuation relationship established (PMD-NORSAR, 2007) but relationship for similar region can be used. Khan (2011) compared different available attenuation model with PGA obtained at different station in 2005 Kashmir earthquake and found that (Ambraseys et al., 2005) attenuation curve gives good results at distances greater than 100 km. For distances less than 100 km it gives lower PGA values as compared to those derived from observed intensities. However, the attenuation curve by (Ambraseys et al., 2005) matches better with the instrumentally recorded PGA values (Khan, 2011).

The Monte Carlo simulation method has been previously used for PSHA e.g. Shapiro (1984), Koyanagi (1999). This method generates synthetic earthquake catalogues using Monte Carlo process, (using controlled random number). Each catalogue represents the next 100 year period in study region and these new events are generated anywhere in region. A synthetic earthquake event is generated from recurrence relationship for N years (N=50 or 100) by randomizing magnitude and epicenter for each new event. An attenuation relationship is used to represent ground motion for each event in catalogue. The highest value of ground motion for each year in the catalogue is saved.

3. Results and discussion

Hazard was calculated for a return period of 475 years with 10% probability of exceedance in 100 years. Ss (0.2sec) & S1 (1.0sec) spectral acceleration maps were generated as a result of Probabilistic Seismic Hazard Assessment (PSHA). Resultant images are shown in Figures 6 and 7 subsequently. Maximum Peak Ground Acceleration (PGA) of 1.21 g occurs in the district of Sibi, while minimum was found in Chaman of 0.03g with 1.0sec (S1) spectral acceleration and 0.65g at Quetta with 0.2sec (Ss) spectral acceleration.

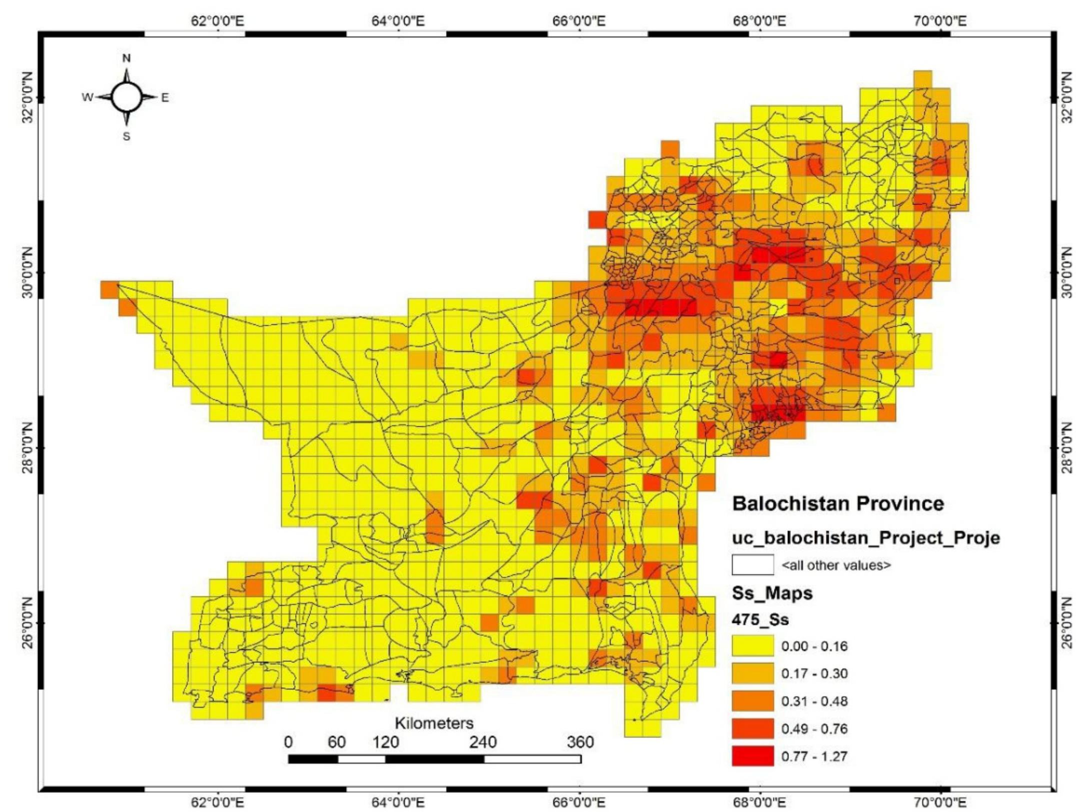

Fig. 5. Ss Map for Baluchistan province, 0.2 Second (475 year return period with 10% probability of exceedance in 100years).

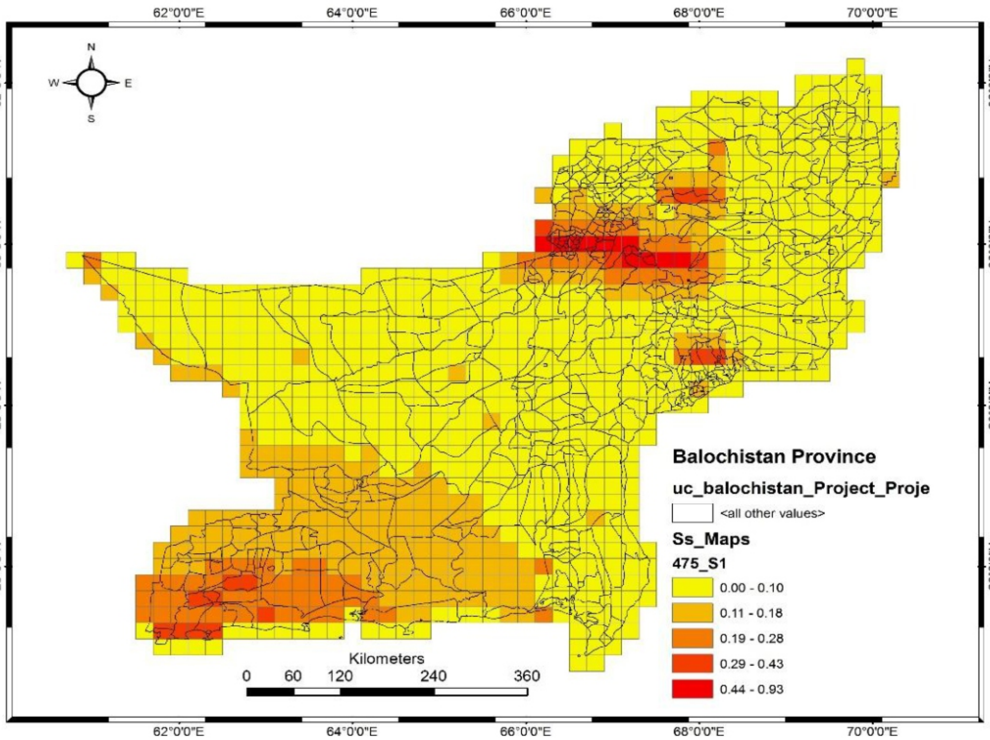

Fig. 6. S1 Map for Baluchistan province, 1.0 Second (475 year return period with 10% probability of exceedance in 100years)

4. Recommendations

The probabilistic seismic hazard assessment of Baluchistan province of Pakistan and subsequent S1 and Ss maps produced as a result of this research are recommended for developing Earthquake Risk Mitigation Strategies for the province of Baluchistan. Further elaboration of the emergency responses for most vulnerable cities of Baluchistan is also recommended.

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