Seismic Hazard Assessment

Probabilistic Seismic Hazard Analysis (PSHA)

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A Review of Mainstream PSHA Methodologies

and their Applications in Pakistan

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Major Developments in the PSHA Methodologies

Early Developments of PSHA Concepts

- Early 1960s
- Ground-breaking efforts (by Cornell and Esteva)

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First Formulation of PSHA

- Cornell (1968). Engineering Seismic Risk Analysis
- Classical Approach

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Generalized Formulation of PSHA

- 1970s
- Using the Total Probability Theorem

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Development of First Hazard Maps

- Cornell (1970). First ‘preliminary’ seismic hazard map for southern California.
- Esteva (1970). First national seismic hazard maps of Mexico (PGA and PGV) for return periods of 50, 100, and 500 years.

C. Allin Cornell (1938–)

Luis Esteva (1935–)

Bulletin of the Seismological Society of America. Vol. 58, No. 5, pp. 1583–1606. October, 1968

ENGINEERING SEISMIC RISK ANALYSIS

By C. Allin Cornell

ABSTRACT

This paper introduces a method for the evaluation of the seismic risk at the site of an engineering project. The results are in terms of a ground motion parameter (such as peak acceleration) versus average return period. The method incorporates the influence of all potential sources of earthquakes and the average activity rates assigned to them. Arbitrary geographical relationships between the site and potential point, line, or areal sources can be modeled with computational ease. In the range of interest, the derived distributions of maximum annual ground motions are in the form of Type I or Type II extreme value distributions, if the more commonly assumed magnitude distribution and attenuation laws are used.

Major Developments in the PSHA Methodologies

First US National Seismic Hazard Maps

- 1976
- Algermissen ST, Perkins DM
- U.S. Geological Survey

2nd US National Seismic Hazard Maps

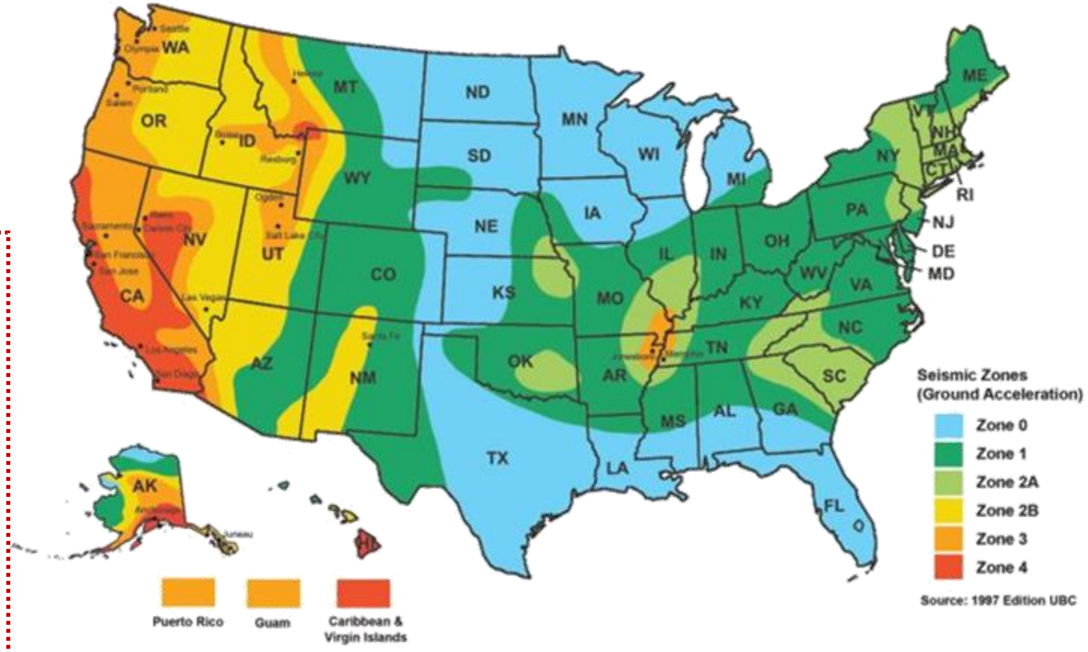
- 1982
- Still based on a formulation that excluded aleatory uncertainty in ground motion estimates.

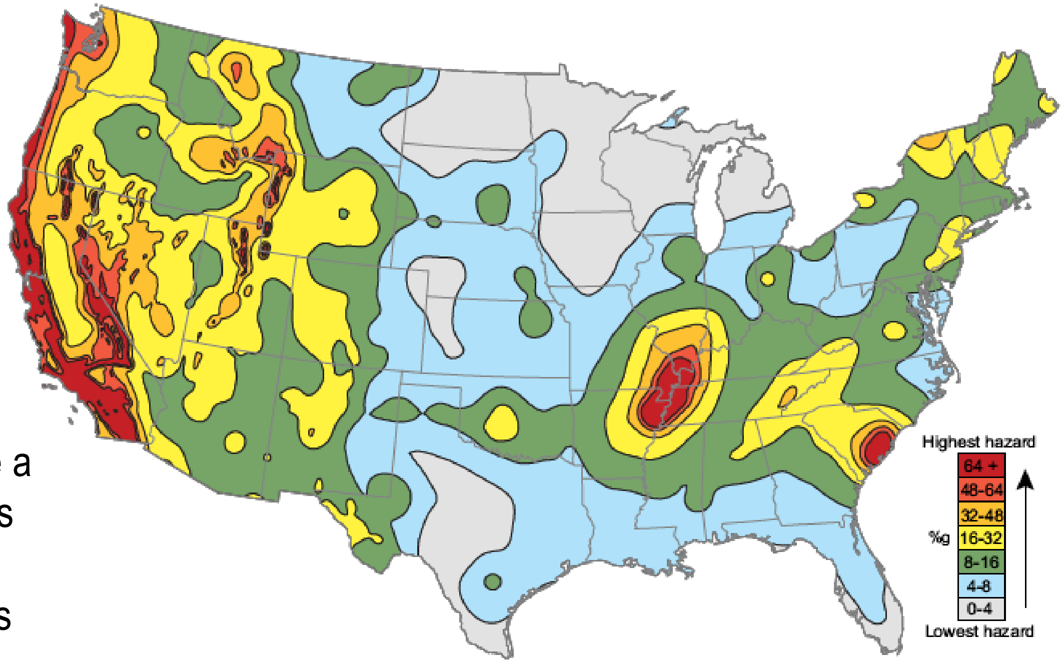
USGS Published Updated Seismic Hazard Maps

- 1990
- Included aleatory uncertainty in ground motion estimates.

Recognition of Finite Segments of Rupture

- 1977
- Earthquakes were recognized to rupture a finite segment of the causative fault, thus becoming a source of energy with finite dimensions rather than a point source as assumed by Cornell.





Major Developments in the PSHA Methodologies

Concept of Uniform Hazard Spectra

- McGuire RK (1974)
- The recognition that ground motion equations and seismic hazard curves could be developed directly on spectral response.

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Arrival of Digital Computers

- Avoiding the necessity of achieving closed-form solutions to the seismic hazard integral.
- Solution techniques based on numerical integration.
- Arbitrarily complex ground motion equations could be used.

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Development of EQRISK and FRISK Programs

- These programs calculated seismic hazard for area sources and faults.

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Deaggregation of Seismic Hazard

- McGuire RK. (1995). Probabilistic seismic hazard analysis and design earthquakes: closing the loop. Bulletin of the Seismological Society of America 1995; 85(5):1275–1284.

Robin K. McGuire

Major Developments in the PSHA Methodologies

The Concept of Spatially Smoothed Gridded Seismicity

- Frankel (1995).
- Nowadays used to compute the USGS National Seismic Hazard Maps.

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Global Earthquake Model (GEM) Initiative

- 2009
- GEM Foundation, Pavia, Italy

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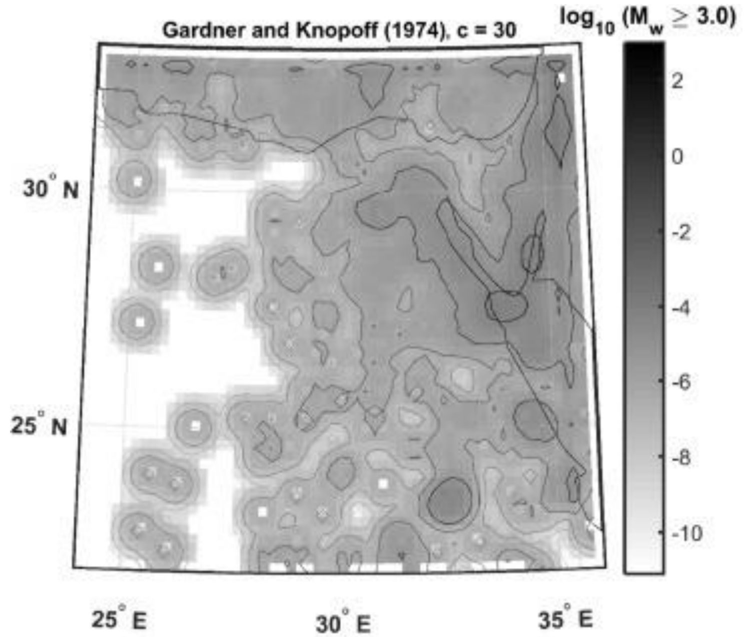
Development of OpenQuake Engine and other GEM Products

- OQ → A state-of-the-art, open-source software collaboratively developed for earthquake hazard and risk modelling.



GEM
GLOBAL EARTHQUAKE MODEL
working together to assess risk

Frankel's Concept of Spatially Smoothed Gridded Seismicity

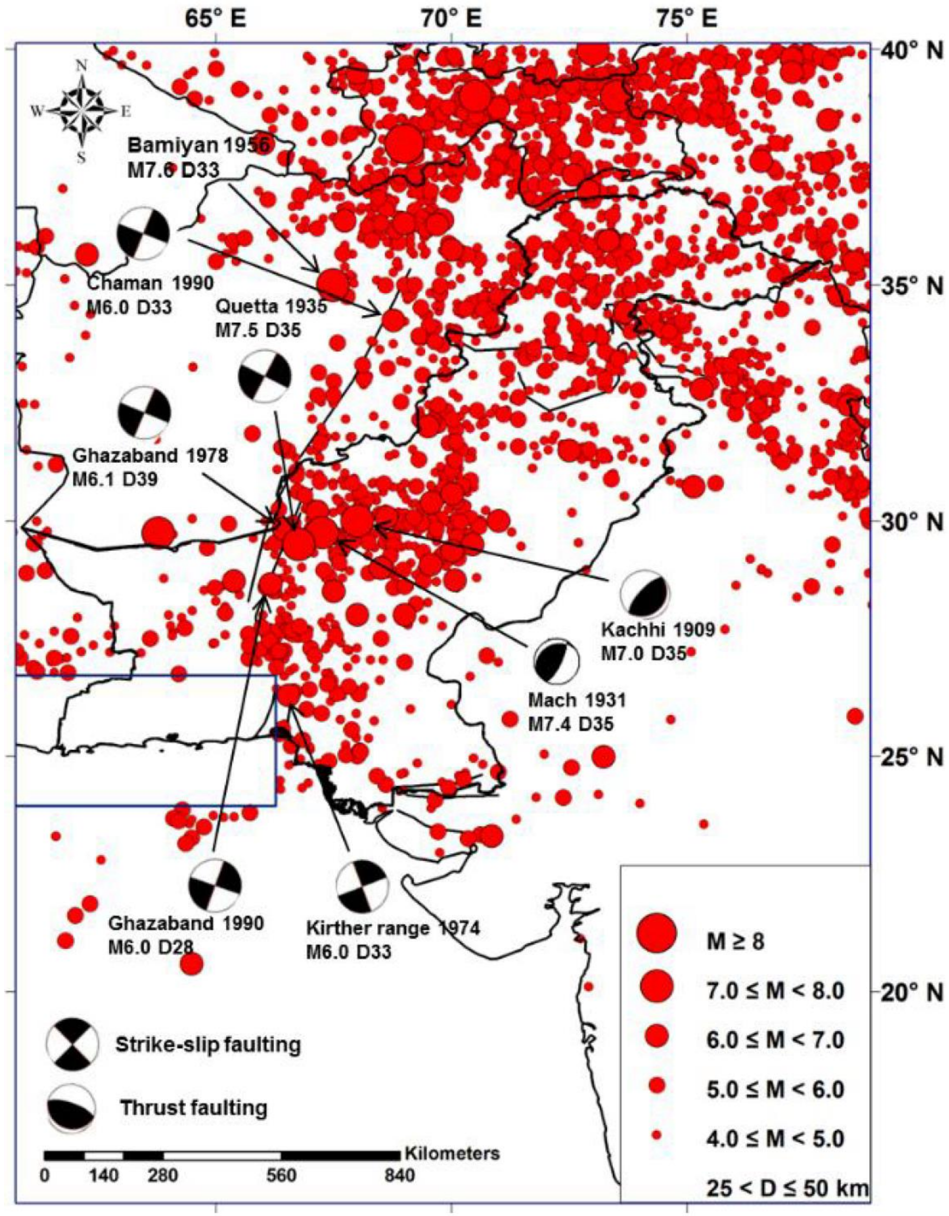
(Frankel, 1995)

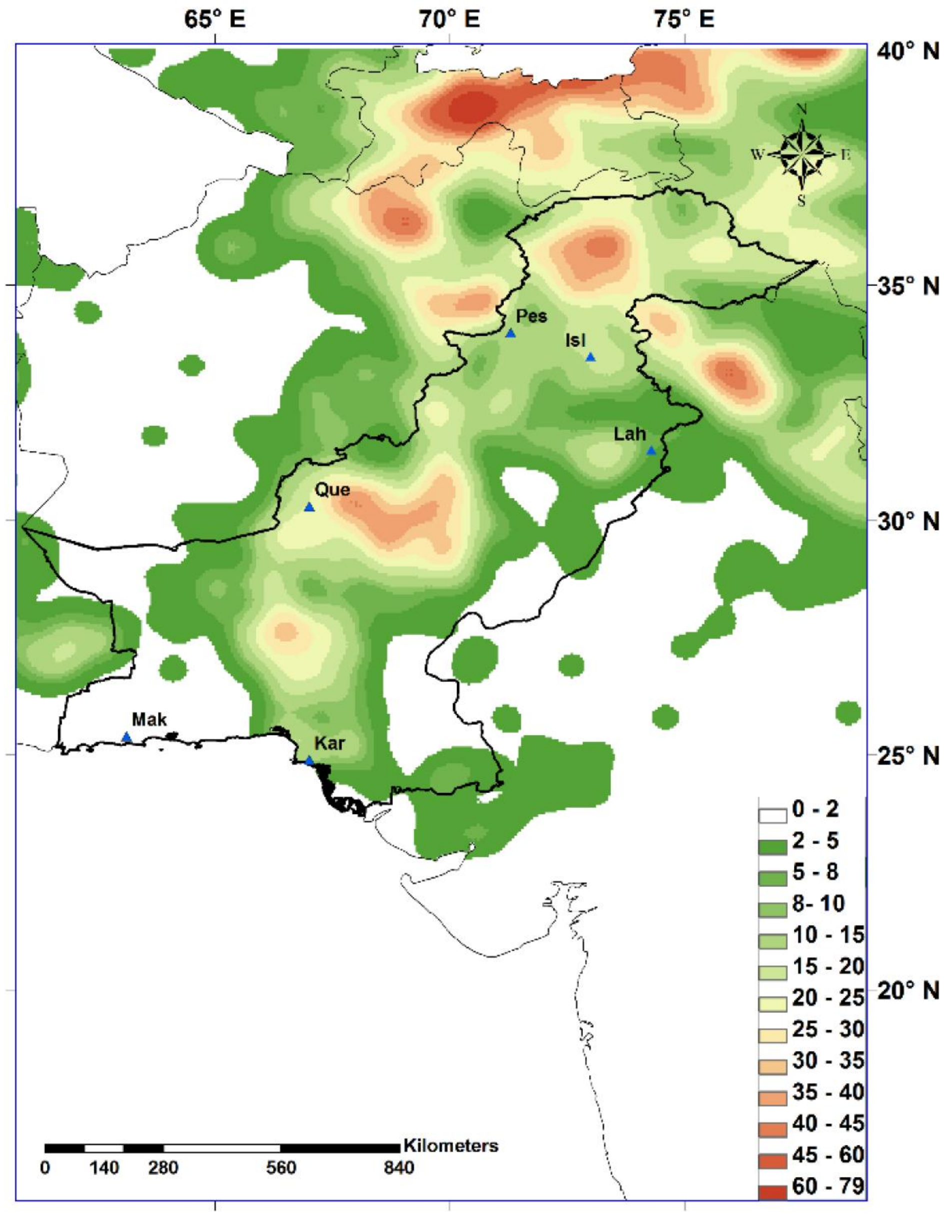
This method models the seismicity that cannot be assigned to specific geological structures, termed as distributed or background seismicity.

The region is divided into square cells, and the number of earthquakes above a certain reference magnitude is counted. This count, that is, the total number of events observed above the threshold magnitude is the maximum likelihood estimate of the a-parameter in the Gutenberg-Richter relationship (Weichert, 1980).

Then, it is smoothed spatially, thus, including the uncertainty in the earthquake location in the final seismic hazard results. To perform the smooth, it is usual to use a Gaussian filter because it preserves the total number of earthquakes.

Finally, the computation is based in the well-known total probability theorem, expressed in terms of rate of exceedance of a certain level of ground motion



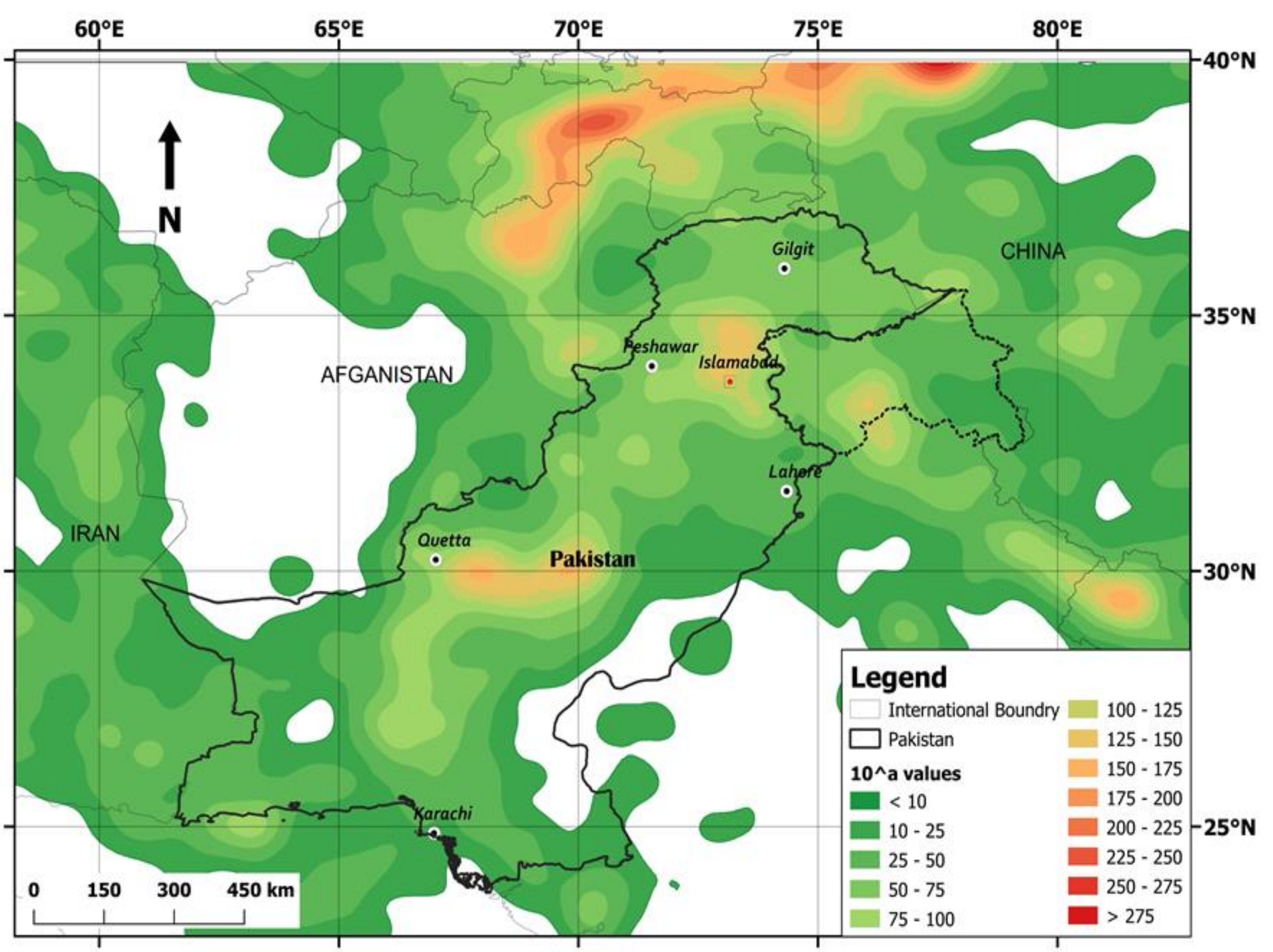


Historical seismicity and smoothed activity rate 10^{a} values.

Source: Zaman and Warnitchai (2016)

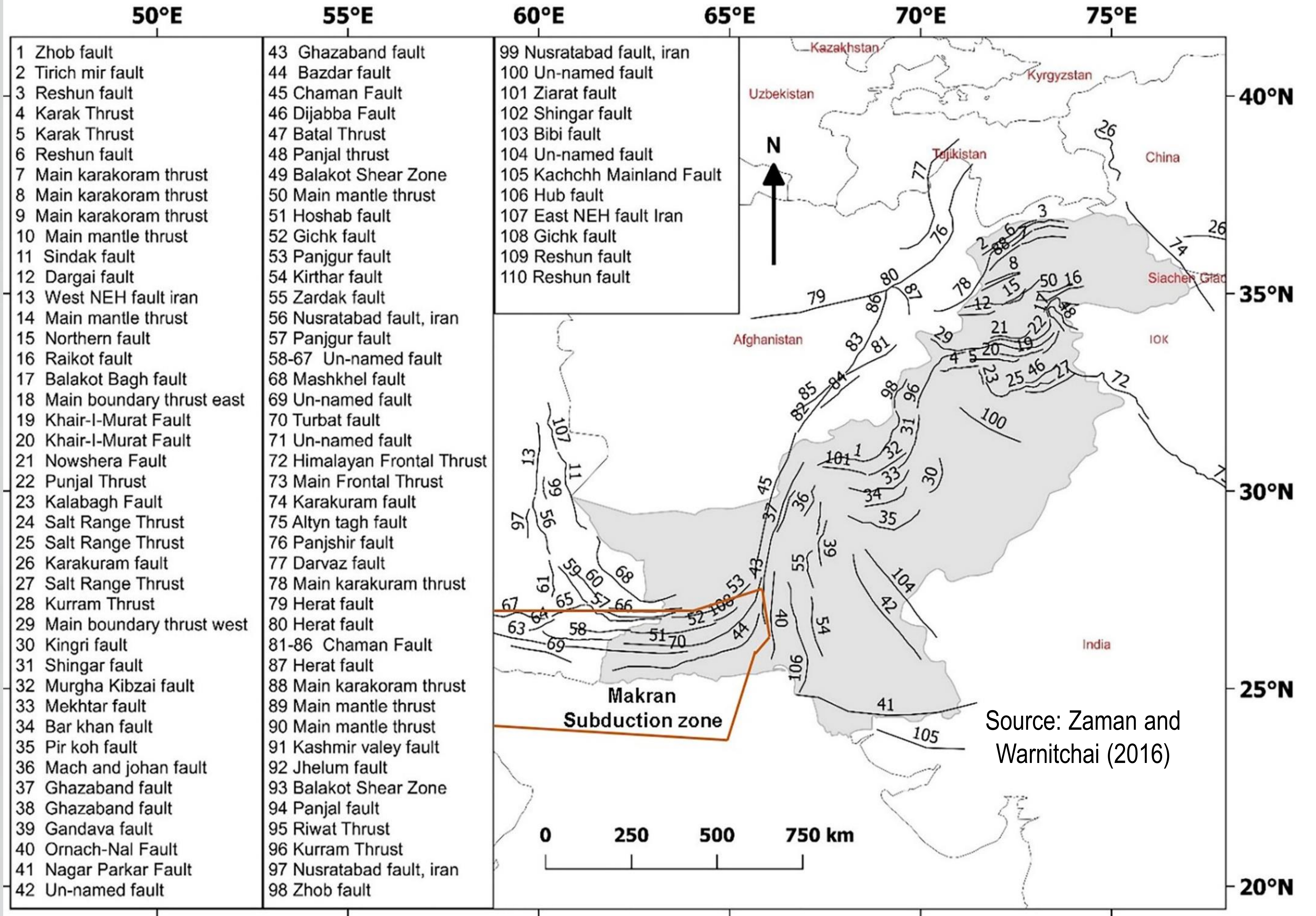
Spatially Smoothed Background Seismicity Approach

$M_w \geq 4.0$, $M_{max} = 7.4$

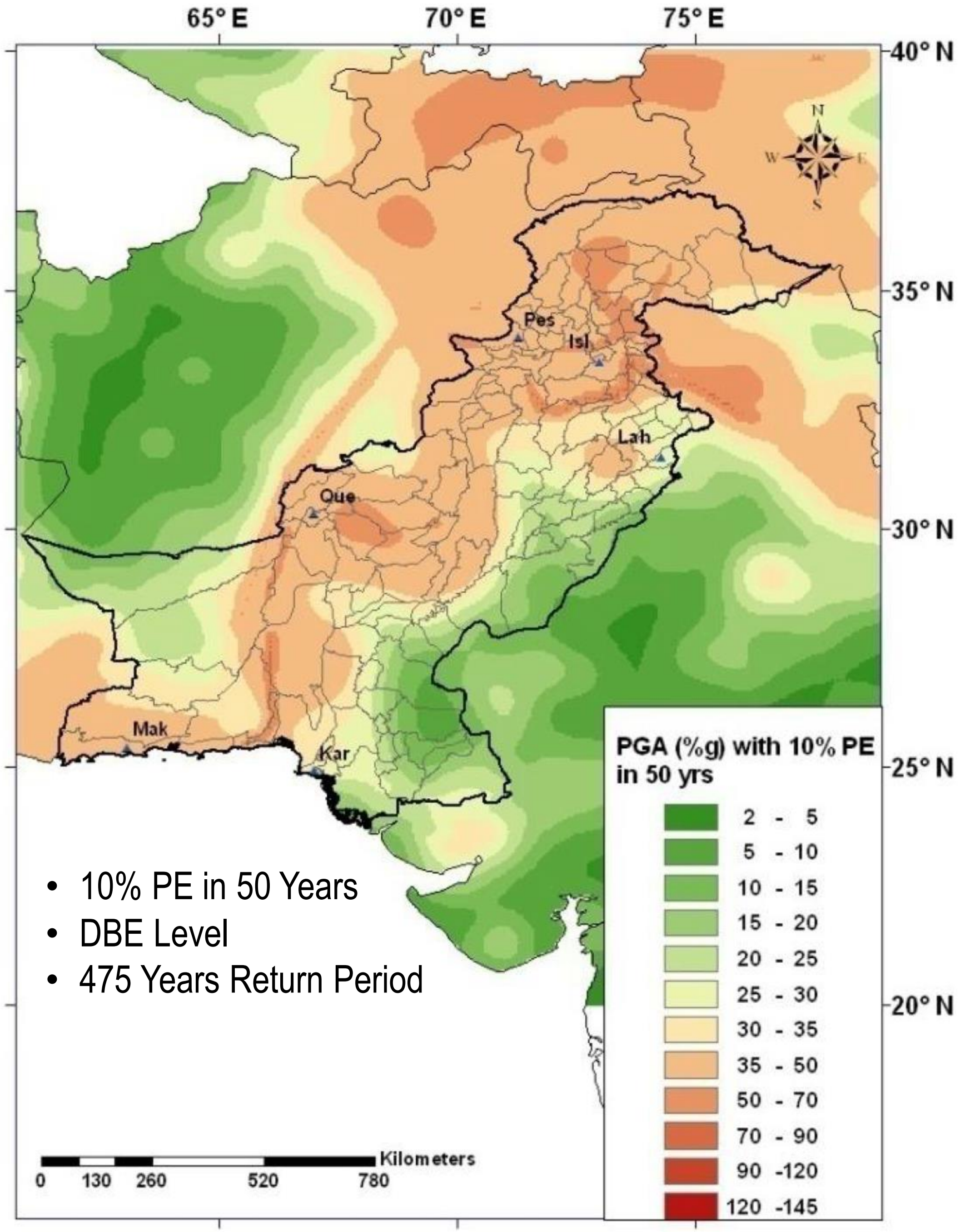


Source: Rahman et al. (2021)

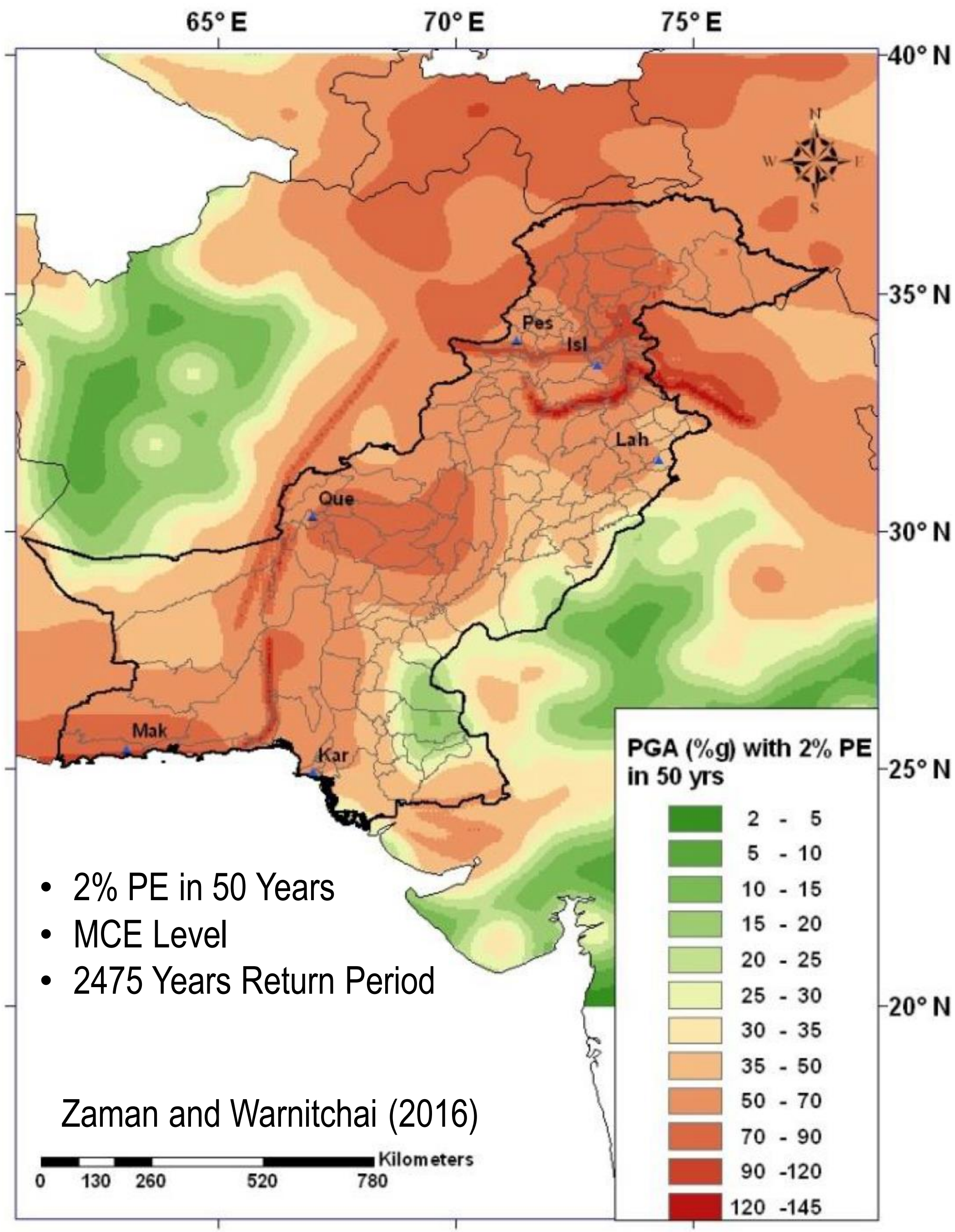
GEM Active Faults Database



Source: Zaman and Warnitchai (2016)



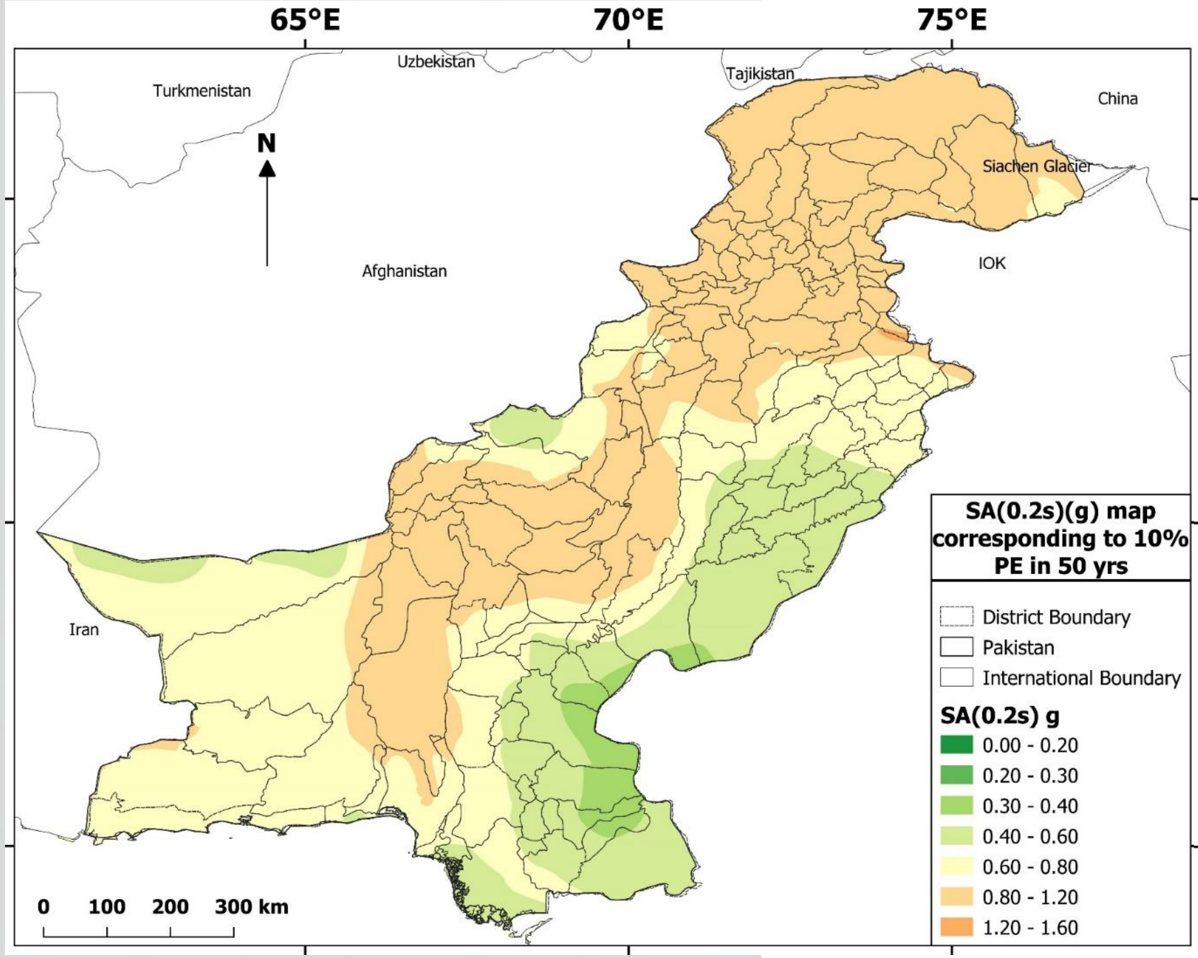
- 10% PE in 50 Years
- DBE Level
- 475 Years Return Period



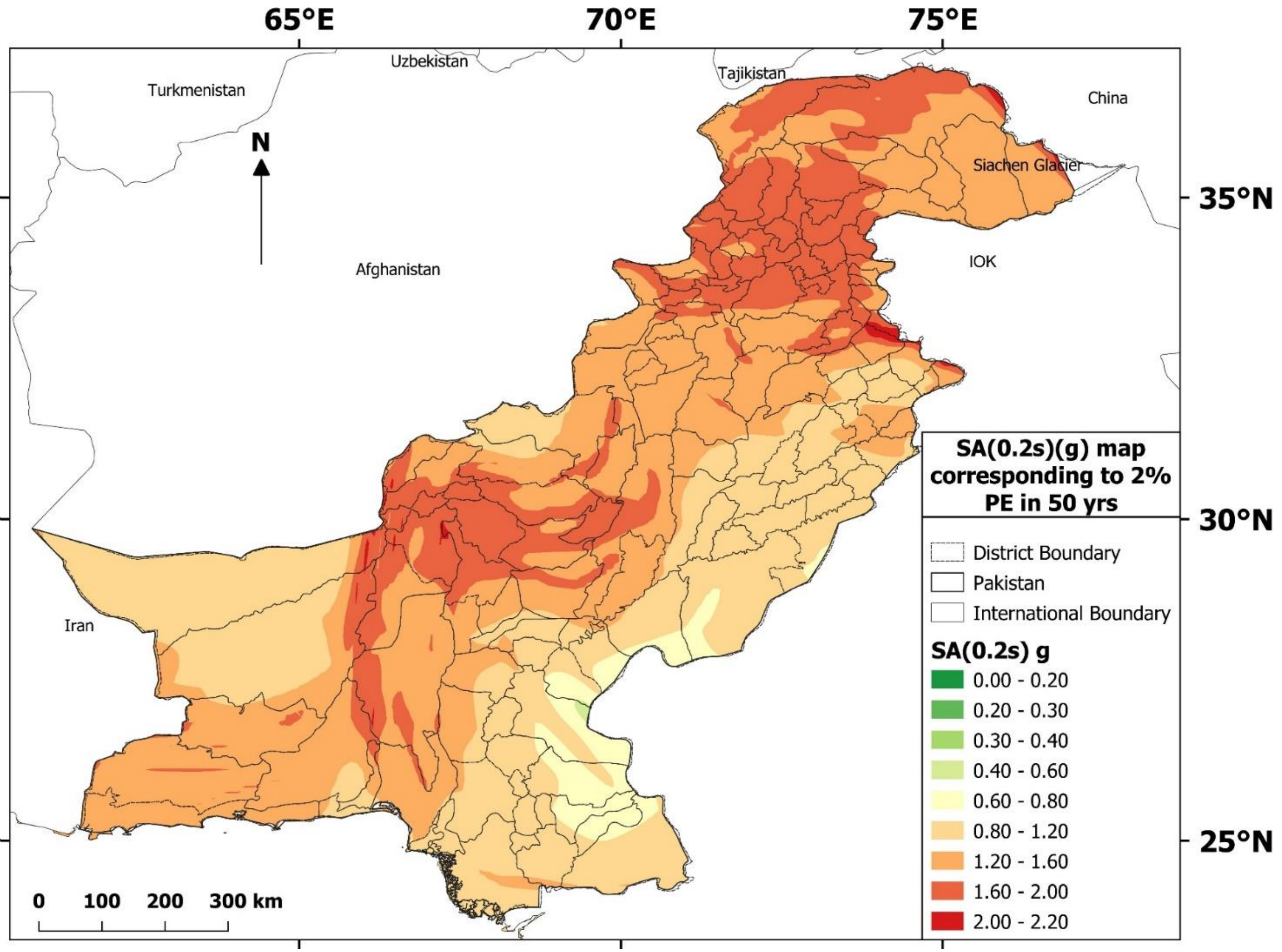
- 2% PE in 50 Years
- MCE Level
- 2475 Years Return Period

Zaman and Warnitchai (2016)

Source: Rahman et al. (2021)



Spectral Acceleration (SA) at 0.2 sec. map for 475 years RP (10% PE in 50 years)



Spectral Acceleration (SA) at 0.2 sec. map for 2475 years RP (2% PE in 50 years)

Thank you for your attention