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Sensitivity analysis and disaggregation of recent seismic hazard assessment in Egypt

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➢Abstract

A recent probabilistic seismic hazard analysis for Egypt is performed in terms of the Peak Ground Acceleration (PGA) and Spectral Acceleration (SA) for 475 and 2475 years return periods. In the current study, an earthquake catalog of Egypt and its surrounding from 2200 BC to 2016 AD .Two de-clustering algorithms, three seismotectonic models, and four Ground Motion Prediction Equations (GMPEs) are implemented through the logic-tree framework to overcome the epistemic uncertainties associated with the seismic hazard inputs. The sensitivity analysis for the declustering algorithms, seismotectonic models, and GMPEs. Sensitivity analysis shows that seismic hazard results of the cities located at the unstable shelf are highly affected with variation in the de-clustering algorithms. Also, the hazard values of these cities are highly affected by the seismotectonic models as the acceleration values obtained by using a regional seismotectonic model are lower than the acceleration values obtained by the detailed seismotectonic models. The results of the disaggregation show that Newbie City is highly exposed to high levels of ground motion in 475 and 2475 years return periods and at the short and long spectral periods (1 sec.) On the other hand, cities located in the NW part of Egypt are highly affected by the long period seismic waves generated by earthquakes initiating at the Hellenic Arc.

➢Hazard calculation

Earthquake hazard analysis has been applied in Egypt using PSHA. The catalogue has been collected from international and local sources. The catalogue spans periods from 2200 BC up to 2016 AD. This catalogue covers the spatial region spanning at 20.00° to 38.00 E° and 20.00° to 38.00º N with unified earthquakes sizes moment magnitude scale **(fig. (1).** PSHA is utilizing Cornell–McGuire (Cornell, 1968; McGuire, 1976) approach.**)** through logic tree **(fig 2).**. Computations have been done using a grid spacing of 0.5°X0.5° using CRISIS 2012 (Ordaz et al. 2012) software code, in terms of rock-site for the (PGA) and Spectral Acceleration (SA) at (0.2, 0.5, 1.0 and 2.0 Sec) for 475 and 2475 years return periods**).** The obtained ground motion acceleration values are contoured, for return period 475 and 2475 to produce hazard contour maps for the PGA and SA (0.2, 0.5, 1, and 2 Sec) as shown in .**(fig.3).**

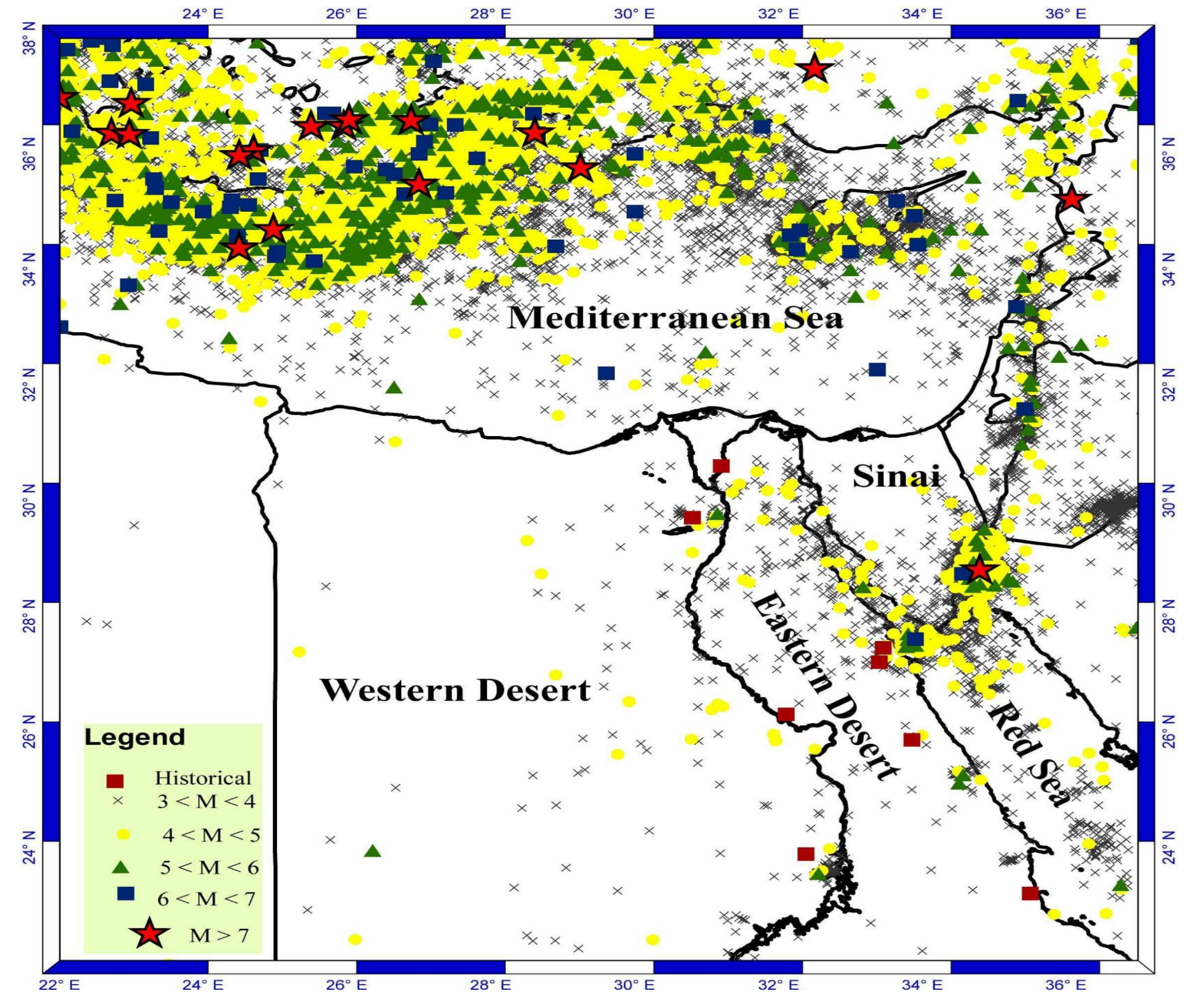

Figure (1): seismicity of Egypt from 2200BC to 2016).

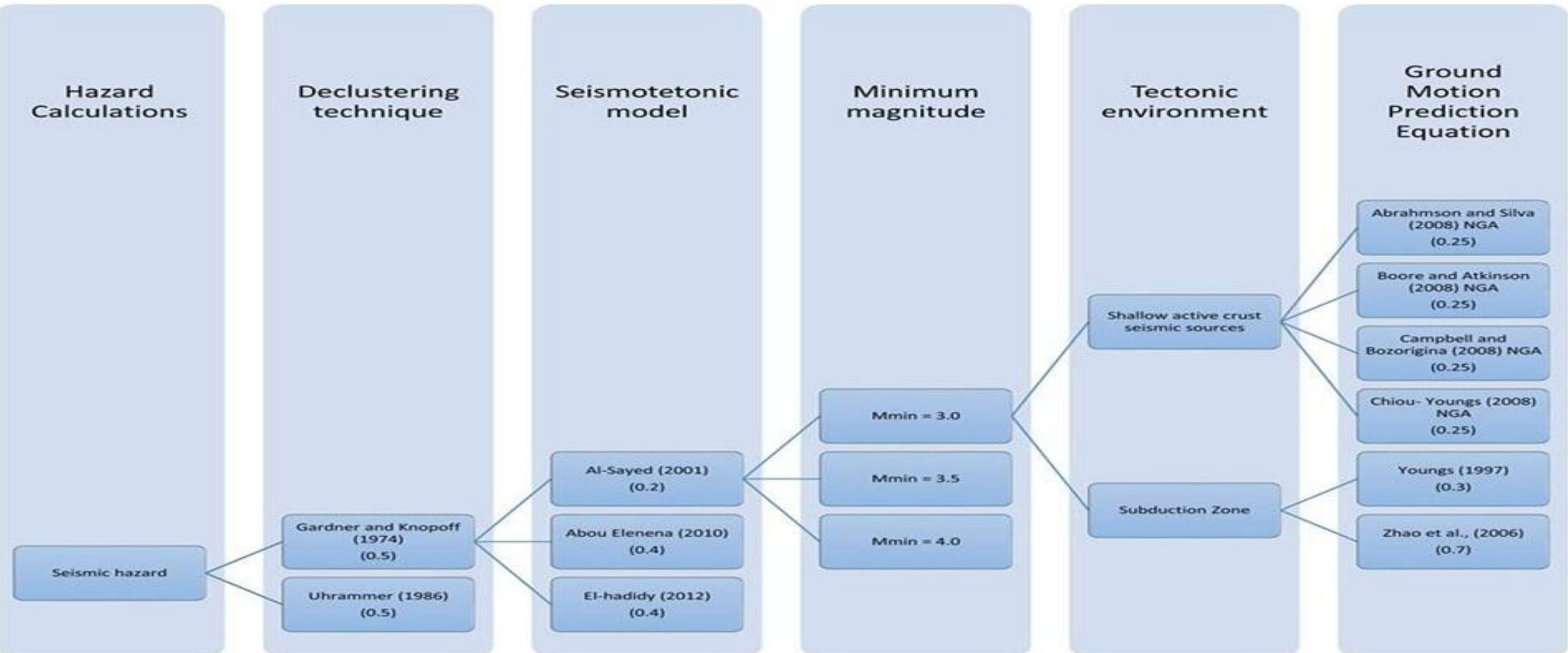

Figure (2): The logic tree's branches implemented in hazard calculation. The given number represent the weight of each branch.

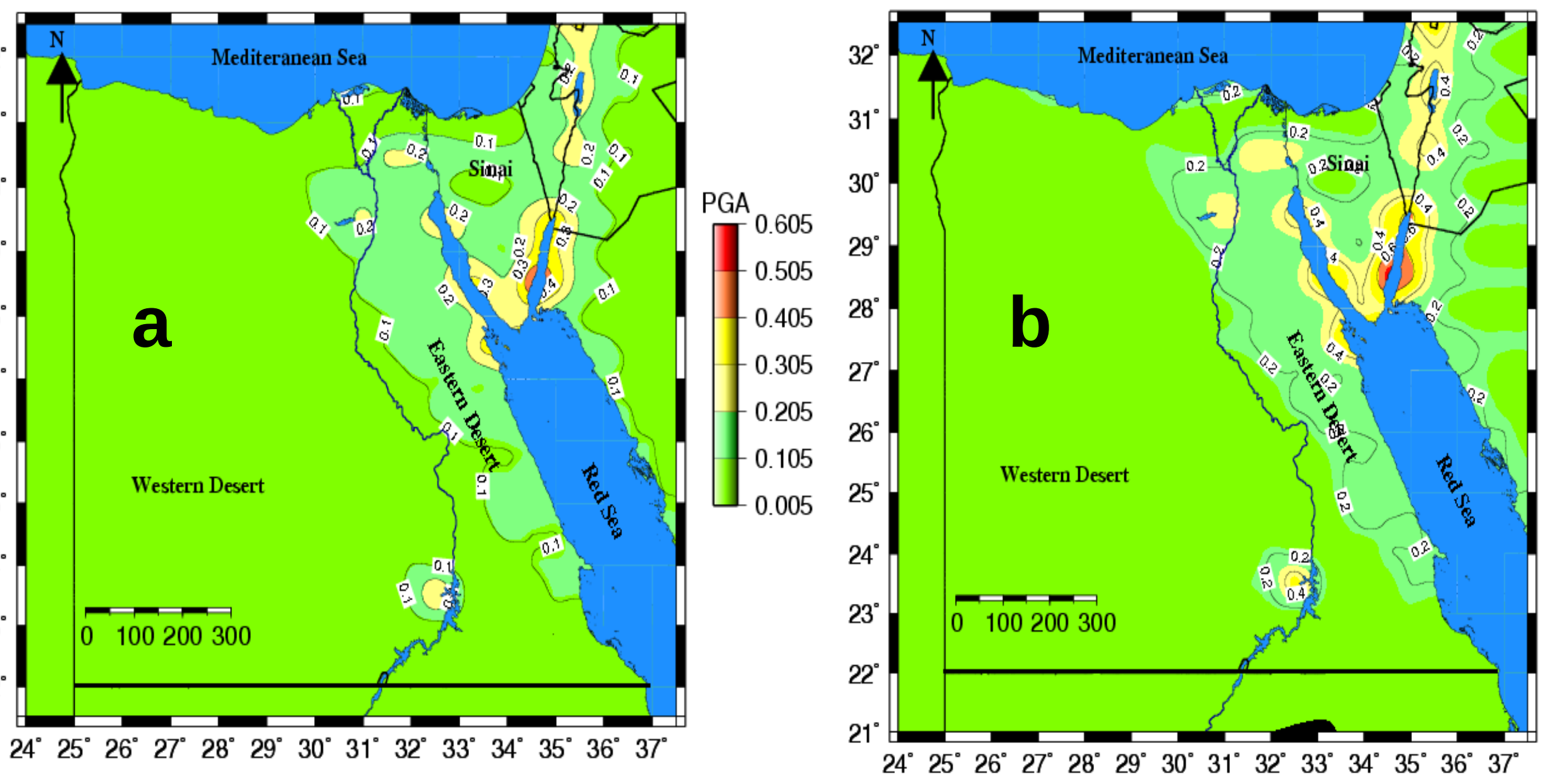

Figure (3): The estimated PGA for Egypt at (a) 475 and (b) 2475 years return periods respectively

➢Sensitivity analysis

Sensitivity analysis is performed to detect which parameters are the most critical for the hazard computation. The aim of the present sensitivity analysis is to view how the variations in the alternative parameter assessments impact PSHA statistics (El-Hussain et al., (2012). Sensitivity analysis (SA) is the study of how the variation (uncertainty) in the output of a mathematical model can be apportioned, qualitatively or quantitatively, to different sources of variation in the input of (Gaber et al., 2018). Sensitivity analysis was investigated for 27 cities of Egypt using two parameters controlling the estimation of (PSHA) in the framework of the Cornell McGuire method; the parameters are (1-seismotectonic model 2- Ground Motion Prediction Equation). The results of the sensitivity analysis **(fig4 A)** show that the models of Abou El-Enenan (2010) and El-hadidy (2012) have similar behavior, while the model obtained by the El-sayed et al., 2001 shows different behavior. We refer the similarity between the models obtained by Abou Elenean 2010 and El-hadidy 2012 to the used data set. Also these two models are detailed models. Also the impact of the selected model is very clear especially for the cities close the active seismic zones in Egypt (e.g Nuwbie city is very close to the Gulf of Aqaba, Sharm El-sheikh and Safaga cities are close to the northern Red Sea, Cairo is close to Dahshour seismic source). The change in the seismotectonic model is little for the cities located at relatively farther distances to the active seismic sources (e.g North Sinai, Damitta, Al-Behira, Kafr Elsheikh and Portsaid) .

The current hazard estimation used four GMPEs (Abrahamson-Silva (2008), Boore-Atkinson (2008) NGA, Campbell-Bozorgnia (2008) NGA, and Chiou-Youngs (2008) NGA) to represent the ground motion generated by the active shallow crust seismic sources. The results of the sensitivity analysis show that there two behaviors to the effect of the selected GMPEs. Effect at the PGA and 0.2 sec. spectral acceleration and another behavior at the long spectral period (1 sec.). Regarding the PGA and short period SA, we can classify the results into cities which has on impact (e.g North Sinai, Damitta, Marsa Matrouh, Alexanderia, Al-Dakhlia and Al-Wadi Algadid), cities with minor impacts (e.g Al-Ismailia, Al-Sharqia, Al-Qalubyia, Cairo, Giza, and Fayoum) (fig 5). And cities with major impact (e.g Nuwbei, Sharm El-sheikh, Safaga). The results of the sensitivity analysis for the cities at long spectral periods (1 sec.) show that all the cities have the same range of ground motion variability**.(fig.4B)**

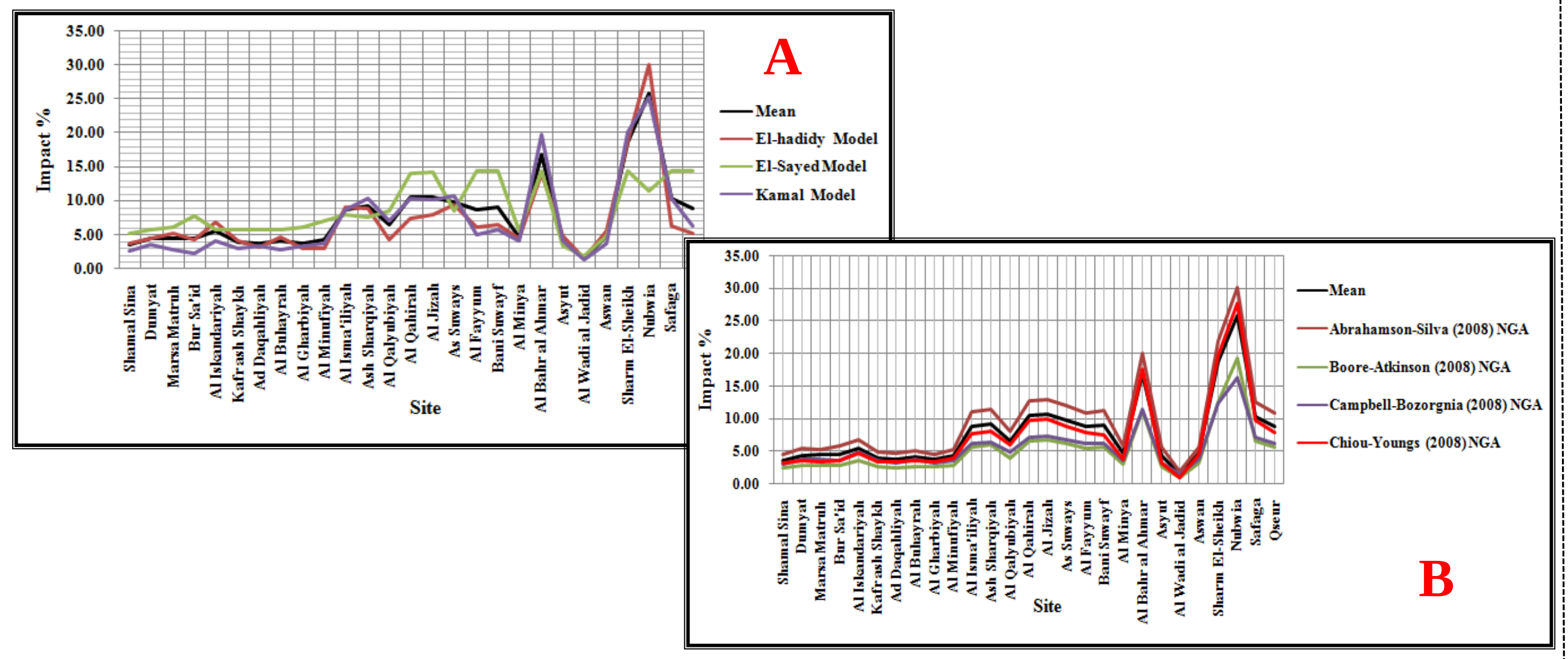

Figure (4):Variation in ground-motion (PGA, 475 years return period) due to the use of different (A) seismotectonic models (B) different Ground Motion Prediction Equations.

➢Sensitivity analysis shows that seismic hazard results of the cities located at the unstable shelf are highly affected with variation in the de-clustering algorithms. **(fig.5)**

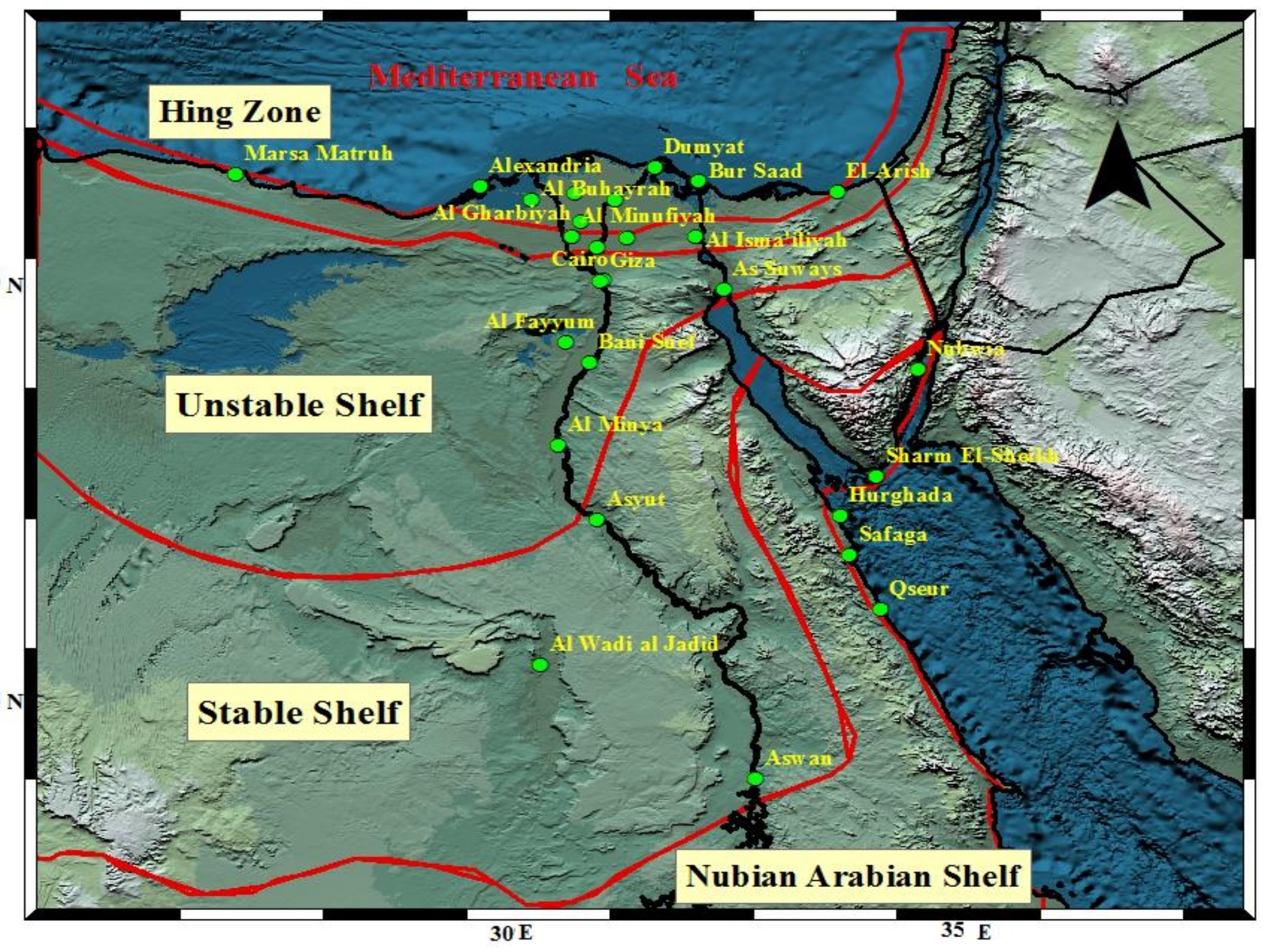

Figure (5): A sketch of the structural aspects of Egypt (after Said, 1962).

➢Deaggregation

Seismic hazard deaggregation was utilized for the first time by Bernreuter (1992). Since this time, deaggregation studies were extensively used, discussed and improved by many authors (e.g., McGuire 1995; Frankel 1995; Harmsen et al. 1999; Bazzurro and Cornell 1999; Harmsen and Frankel 2001; Pelae´z et al. 2002; Tselentis and Danciu 2010; Abdi et al. 2013).seismic hazard values were deaggregated to determine the sources that contribute at hazard levels of 27 Egyptian cities by using CRISIS 2012 (**Ordaz et al. 2012**). The deaggregation utilized for PGA and SA (0.2, 1Sec) at 10 and 2 % probability of exceedance in 50 years (return period of 475 and 2475 years). The deaggregation study will help determine the distance and magnitude values that are mostly participating in the hazard, at certain cities. **(fig (6)**. A straight analysis of geographic deaggregation enables us to identify sources involved in the hazard, such as active faults, and to determine predominant earthquakes for a site (Marin et al., (2004). Results of the deaggregation are shown in **table (1).**

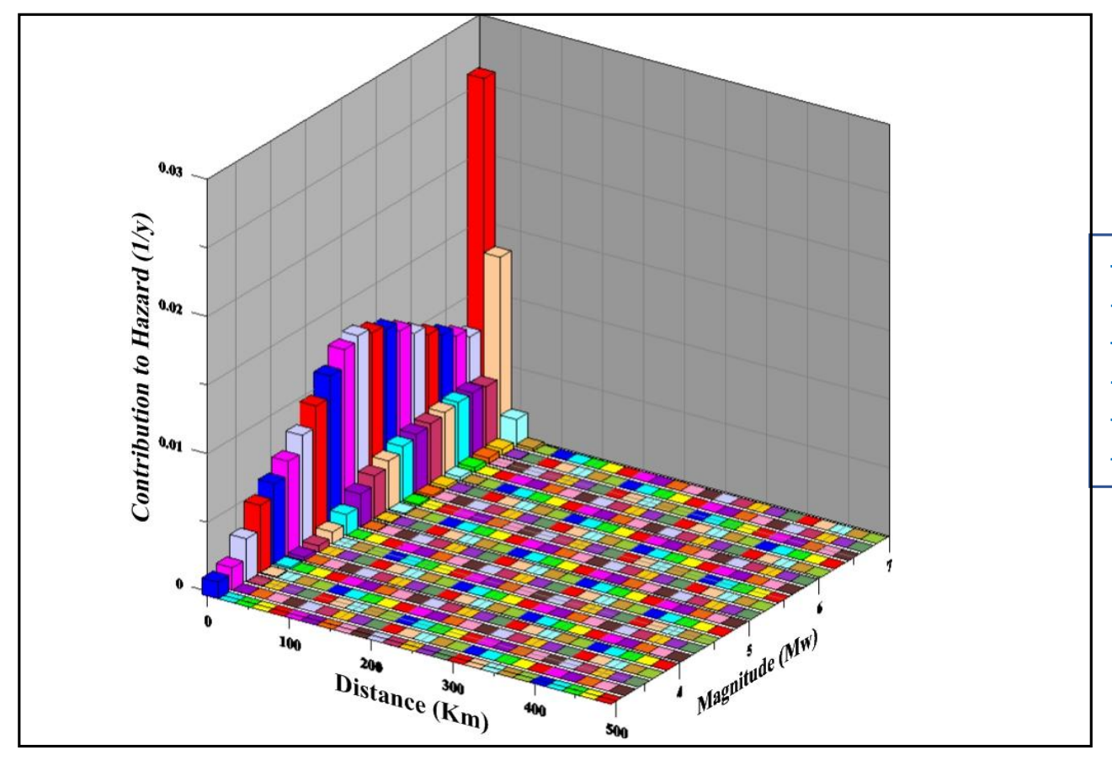

Figure (6): Deaggregation results at PGA for 475 year return period at NUB (Nubwia)

Table (1): Deaggregation of seismic hazard for return period 475 year at (PGA, 0.2 and 1s)

City	PGA 475 y		0.2s 475 y		1.0s 475 y	
	D (Km)	M_w	D (Km)	Mw	D (Km)	Mw
Ad Dakhaliya	50.33	5.08	66.56	5.01	295.96	6.76
Al Iskandaryah	36.35	4.74	40.9	4.7	284.01	6.76
Al Ismiliyah	20.7	4.52	18.17	4.64	148.46	6.21
Al Mnofiyah	53.71	5.04	53.61	5.03	273.43	6.64
Al Wadi el jadid	48.45	4.36	68.74	4.41	394.57	6.35
Al Buhyria	50.63	4.89	53.44	4.89	305.75	6.8
Al Fayyum	22.91	4.61	23.96	4.57	128.93	6.12
Al Gharbiyah	59.34	5.1	62.17	5.1	293.31	6.74
Al Gizah	20.33	4.64	21.76	4.54	108.44	6.01
AlMinya	28.84	4.46	32.13	4.45	252.45	6.41
Al Qahirah	20.37	4.63	21.83	4.54	111.09	6.02
Dumyat	45.29	4.78	44.79	4.78	292.87	6.74
Aswan	44.56	5.08	46.28	4.96	152.12	6.11
Al-Qalibiyah	30.13	4.81	36.62	4.63	226.34	6.41
Al-Sharqiyah	19.32	4.54	20.35	4.51	167.24	6.25
As Suways	20.91	4.58	22	4.54	129.39	6.21
Asyut	30.65	4.36	30.44	4.36	272.27	6.47
Bahr Al hamer	17.66	5.14	18.86	5.01	52.09	6.08
Bur Saad	35.2	4.66	40.15	4.65	281.13	6.69
BaniSuef	20.12	4.39	21.26	4.36	158.15	6.07
Kafr Ash Sheikh	53.75	4.98	56.44	4.97	301.97	6.79
Marsa Matruh	55.8	4.93	64.01	4.94	302.47	7.26
Nubwia	16.54	5.66	17.35	5.45	25.57	6.35
Quser	23.95	4.61	25.5	4.57	128.01	6.23
Safaga	24.97	4.76	27.5	4.7	104.56	6.19
Shamal Sinai	69.72	5.32	72.54	5.24	210.75	6.57
Sharm El-Sheikh	17.63	5.1	18.99	4.98	46.59	6.14

Conclusion

The sensitivity analysis and seismic hazard disaggregation are performed to determine the impact of the different alternatives used by Gaber et al., (2018) and to indicate the sources having high contribution in producing the ground motion at the major cities in Egypt. The seismic hazard maps show that the high values of ground motion are concentrated in the NE part of Egypt around the Gulf of Aqaba, Gulf of Suez and Northern Red Sea. The results of the used seismotectonic models show that regional seismotectonic models (old) (e.g El-sayed et al., 2001) are less efficient than the modern ones. Recent seismotectonic models based on the recent seismicity data obtained by the ENSN show similar behavior and the generated ground motion are almost equal. Another aspect is detected, this aspect is that the cities close to the active seismic sources (e.g the Gulf of Aqaba, Gulf of Suez and Northern Red sea) are highly affected by using different seismotectonic models. On the other hand the change of the seismotectonic model has less impact on the sites located far from the active seismic sources. Concerning the effect produced by the use of different GMPEs, we notice that for the PGA and short period spectral period, the ground motion values are highly affected by using different alternatives of the GMPEs. This great variation reflects the urgent need of estimating local GMPE for Egypt especially for the PGA and short period SA. While the impact of using different GMPEs has less impact on the Ground motion calculation at longer spectral periods (1 Sec.). Results of the deaggregation of seismic hazard show that the PGA affecting the major cities in Egypt have high contribution of the seismic sources located at distances 15 km to 70 km generating earthquakes having magnitudes ranging between 4.3 Mw and 5.6 Mw. While at longer spectral periods have the magnitude range of 6.0 Mw and 7.2 Mw located at distances 25 km to 305 km.